NASA RESEARCH ON PROMISING V/STOL AIRCRAFT CONCEPTS

By

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This presentation is concerned with the National Aeronautics and Space Administration's research program on Vertical-and short-take off and landing aircraft.

As an introduction however, it may be desirable to give a brief rundown on the NASA Office of Advanced Research and Technology under which the overall Aeronautics program is handled. This office is charged with providing the technology required for the future steps to be taken in meeting the nation's aeronautical and space objectives. The work of the Office of Advanced Research and Technology--or OART--utilizes about ten per cent of the NASA budget, a third of the employees, and some of the major field installations. Seven program divisions are supported under OART and five research centers. The total support for the Aeronautics Division, this year, will be about 95 million dollars. Of this, approximately 13 million has been assigned to cover research on vertical and short take-off and landing--or V/STOL aircraft.

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Flight and wind-tunnel model studies are carried out at our Ames Center in California and the Langley Center in Virginia; V/STOL engine-component research is carried out primarily by the Lewis Research Center in Cleveland.

Over the past 15 years, many different aircraft concepts for achieving a V/STOL capability have been investigated by the industry, the military services, and the NASA. The next figure indicates the wide variety of V/STOL "test beds" that have been investigated since then. These investigations have indicated that many of the concepts are not promising enough to be studied further; most, however, have provided some contribution to the state-of-the-art of general V/STOL design requirements, and several--like the tilt-wing--are considered very promising and have evolved to preprototype military aircraft versions. Except for the helicopter, no aircraft capable of vertical take off and landing has yet been put into production; however enough test data and experience have been accumulated to justify studies to compare the potentiality of the various concepts for particular missions or applications. One application recently receiving increased attention is commercial short-haul transportation.

It has been predicted that by 1985, more than 130 million people--50% of our total population then--will be living in the three super metropolitan areas shown on this

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figure. Within these and other large urban areas--both here and in other countries--an increasing demand will exist for an "air bus" to provide more satisfactory, faster short-haul transportation. In addition, although air shipment of goods will probably never account for a large percentage of the total freight business, the airplane will become increasingly important in the movement of certain high-value commodities. Ability to deliver such commodities closer to their distribution point further emphasizes the need for "close in" near city-center STOL of VTOL operation. A variety of VTOL or STOL aircraft have been proposed by designers to satisfy the requirements of such transportation.

Last year, the NASA negotiated contracts with three U.S. airframe manufacturers, having airline partners, to conduct the necessary engineering, analysis, and design studies required to determine which VTOL or STOL concepts were most promising for development into successful, operational, commercial short-haul transports in the 1970 time period, and to indicate problems requiring further research. Although the contractors gave major emphasis to the area of aircraft design, consideration of flight-operation and economic aspects were included to make the studies realistic. The NASA specified the aircraft concepts to be studied initially--and each contractor added others it considered likely to be competitive.

The aircraft were sized for specific range and passenger capacity, again according to NASA guidelines. A typical route, shown in the next chart, was used in the contractors' studies, and illustrates a possible application for V/STOL commercial aircraft. Airports A, B, and C are located within one large metropolitan area--airports D and E are in another 300 miles away, and airport F serves a smaller city or town in between.

Three contractors were chosen to conduct the studies to bring to light areas of possible technical disagreement, ensuring that the results were based on solid engineering data and analysis, rather than only opinion or possible prejudice. Typical configurations studied are illustrated in the next two charts to give you some idea of the type of aircraft evaluated. The first shows the concepts considered for short take-off and landing operation; of these the deflected-slipstream and turbofan types have already reached the prototype stage. The vertical take off and landing concepts studied are shown in the next figure and include the tilt-wing--which has reached prototype status with the Air Force's XC-142 aircraft; also included are an advanced helicopter designed to stop, fold, and stow its rotor in flight to improve cruise performance; and two jet or fan types. The basic payload for all designs was 60 passengers, but consideration was given to the effect of increasing the aircraft size to accommodate 90 and 120 passengers.

The next figure again indicates the concepts considered by each of the contractors, which were Boeing, Ling-Temco-Vought, and Lockheed. Of the many types considered, those emphasized in white (underlined) were felt to be most promising by the individual contractors. Although several concepts remain, the less-attractive versions of each type--economically and technically--were also eliminated. The determination as to which types were most promising was established by comparison of estimates of such contributing factors as technical development risk, extent of research required, direct-operating cost, original-acquisition cost, noise, and passenger appeal. One of the primary influencing factors for a commercial vehicle is, of course, direct-operating cost. It is usually expressed in cents per seat mile and covers such items as crew salary, fuel and oil, insurance, and maintenance.

The variation of direct operating costs with stage length for the 120-passenger aircraft is shown in this figure. A band of values is shown for the V/STOL aircraft and the the STOL aircraft, as well as for the latest current short-range conventional take-off jet aircraft carrying 90 to 125 passengers. In general, the STOL aircraft have direct operating costs about 30 percent lower than those of the VTOL airplanes. It also appears that the STOL aircraft can have direct operating costs of about the same value as the new subsonic jet transports carrying 90 to 125 passengers.

Present indications are that the propeller STOL and turbofan STOL aircraft could be designed and constructed by 1970; however, the VTOL aircraft would require five to ten years longer for research and development in various areas to attain values of direct operating costs indicated here.

These contractor studies have recently been extended to cover additional design, performance, and cost trade-off aspects found to be inadequately covered in the original studies. However, from these studies--and related ones supported by the Federal Aviation Agency and the Department of Commerce--we feel we now have a better understanding of the technical state of the art and of major problem areas for this type of aircraft. Based on these studies, it appears the potential for an acceptable, safe, and economical STOL or VTOL transport is good for several concepts. Considerable research and development in many areas of aircraft design, aerodynamics, propulsion systems, handling qualities, and structures are required, however, to meet the requirements for commercial transportation.

The studies also indicate the need for advanced systems at the terminal area for guidance of the aircraft to enable better control, reduce the time involved during instrument-flight conditions, and improve the safety of these aircraft.

The NASA therefore plans continued and expanded research on several STOL and VTOL types felt to be especially promising.

I would like now to describe recent and proposed NASA research on some of the more important aeronautical problem areas indicated by the studies. For convenience, we have divided the program into four V/STOL aircraft types--or research missions: the short take-off and landing short-haul transport; the vertical take-off and landing transport; the advanced helicopter; and the VTOL tactical fighter.

The next figure indicates some of the major critical aeronautical problems delaying development of the advanced STOL short-haul transport.

To fly safely into the small areas proposed for this kind of operation, a very low-speed, high-lift capability, is needed--not available with conventional aircraft flap systems. Power can be used to augment the aerodynamic lift in low-speed operation but this use must be accomplished efficiently--especially for a commercial vehicle--because of the severe reductions in payload and range than can be associated with excessive fuel usage in this low-speed flight regime. Recent wind-tunnel research has indicated several promising concepts for obtaining the higher power-augmented lift desired, though they do involve a more complex approach than the simple conventional-flap system.

One of these is the rotating-cylinder flap, appropriate for a propeller driven aircraft requiring very high STOL performance but only moderately-high cruise speed.

This concept utilizes a spanwise cylinder mounted at the leading-edge of the wing flap, hinged to extend slightly above the upper surface when the flap is deflected. Analytical studies conducted previously by Stanford University, and small-scale experiments in an NASA 7-by 10-foot wind tunnel indicated that rapid rotation of the cylinder in the direction of the airflow would re-energize the air boundary layer over the aft portion of the wing, maintaining flow attachment with the flap deflected to high angles. This would produce a larger angle of turn to the airflow and a significant increase in lift.

Full-scale tests were recently conducted in our 40-by 80-foot tunnel of this flap concept mounted on the COIN--or Counter Insurgency--type model illustrated here. The next figure indicates typical results obtained in these tests, showing the effect of cylinder-rotation speed on lift. The increment in lift of the rotating-cylinder-flap over that of a conventional flap, (for the test conditions) is shown to increase with increasing rotation speed. Initial indications are that the power required to rotate the cylinder at the speeds needed would not be large, roughly ½ horsepower per foot of cylinder length. It is planned that this high-lift approach will be carried to flight research--probably next year--to determine if this lift augmentation concept can be integrated successfully into a complete aircraft system, and to bring to light and study any new significant aeronautical problems.

Another concept, for obtaining increased lift for jet-powered higher cruise-speed STOL aircraft, has been proposed by the de Havilland Company of Canada, based on results of small-scale, two-dimensional tests. The operation of this system, called the augmentor-wing concept is illustrated in this cross-sectional view of the wing. Primary air--for example, air bled from the jet-engine compressor--is ejected into the augmentor channel drawing in secondary air from the wing upper and lower surfaces, increasing the downward flow through the channel and increasing the lift. It can therefore be considered as a method of providing for a jet vehicle, the beneficial increment in lift resulting from the slipstream of propeller-driven aircraft. We began tests last year of a ½-scale aircraft model provided by de Havilland, in a joint program with the Canadian Defence Research Board. The model is shown next mounted in the 40-by 80-foot wind tunnel. The results of these initial tests show that the augmentor-wing principle is effective in producing high values of lift with moderate values of augmentor jet thrust.

Such lift capability could make the jet STOL aircraft more competitive with a prop STOL vehicle.

Next year we plan to extend the wind-tunnel program to cover an improved more sophisticated flap design, again in a joint program with the Canadian Defence Board. Consideration will also be given to the modification of a conventional transport aircraft to extend this research to flight to verify the potential of this system.

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The low-speed flight characteristics of large STOL aircraft--and the criteria for establishing control response and damping requirements--have been studied for several years by the NASA with available conventional transport aircraft having simpler flap systems than those described a few minutes ago. Such handling quality information is needed for the optimum design of future STOL aircraft control systems, and of suitable automatic stabilization equipment, for example. We plan soon to conduct limited flight tests with the more advanced Breguet 941 STOL transport. The vehicle will enable us to help define the most critical tasks and most practical operational procedures for large STOL aircraft in the terminal area--at least down to about 55 knots, the lower limit of flight with good and safe handling qualities with this aircraft.

Because the deflected-slipstream concept used on the Breguet 941 is considered promising for STOL propeller-driven aircraft, we plan to extend these studies somewhat later with more comprehensive flight tests of the Ling-Temco-Vought XC-142 aircraft. This aircraft is much more versatile than the 941, having a variable-stability system permitting changes in control power and stability, in addition to a broader range of descent conditions with its tilt-wing feature. It is designed to operate as a VTOL aircraft but speeds down to about 30 knots would probably be covered in our STOL investigation.

Capability of operating under near zero-visibility weather conditions is a major goal for any regular commercial operation. Several military and FAA-sponsored programs are studying all-weather landing systems which depend on rather extensive ground equipment. The NASA is now investigating a promising landing approach system that would require little ground equipment, permitting utilization of small airports not having such equipment, including fields in relatively undeveloped areas. Fairly extensive - and presently bulky - on-board equipment is needed in the system studied to measure the location of the aircraft relative to the landing site, and to generate a display of aircraft attitude and position information to the pilot. The display presents a simplified view of a runway as it would appear during a visual approach; the pilot then uses essentially the same landing technique he would use for visual flight. Initial flight tests are being made with a conventional propeller transport aircraft--to check out the elements of the system - which appeared very promising based on previous ground-based simulator tests. Successful integration of the components into an operating "bread-board" system would be followed by transfer of it to a more representative STOL aircraft--such as the XC-142A--to evaluate its effectiveness in actual short-landing operation.

The second NASA research mission is the vertical take-off and landing short-haul transport. The initial application of this type will probably be for a military aircraft, although development of such a vehicle would, of course, have a strong influence on the later commercial design. Incidentally, the V/STOL transport research to be reported on under this "mission" will not include that on the helicopter which will be described separately.

The next figure indicates what are considered to be the general critical aeronautical problem areas for this vehicle.

The contractor studies indicate that the tilt-wing VTOL concept would have fewer technical problem areas than most of the other concepts for the 60- to 90-passenger aircraft. We feel this condition is partly a result of very extensive wind-tunnel model and some flight research by the NASA over the past several years. However, some work is necessary to reduce the drag levels of the aircraft and improve propeller performance to attain cruise velocities of the order of 370 knots. In addition, the larger 120-passenger aircraft may need six propellers or special techniques for control, such as fast-response variation of wing tilt for controlling the pitching moments.

Military-Service flight experience with the XC-142 tilt-wing V/STOL research aircraft has confirmed results of past wind-tunnel studies indicating that self-created disturbances can be created in flight near the ground which can adversely change the aircraft characteristics. NASA flight studies are planned to obtain a better understanding of these effects, and of the general control and damping requirements during hovering flight and during the transition from conventional forward flight to hovering.

The primary aircraft planned for use in this study, is, again, the XC-142A tilt-wing V/STOL aircraft mentioned in the STOL discussion. In addition to ground-effect studies, examination will be made of the applicability to large V/STOL aircraft, in general, of current flying-qualities criteria in hover and transition--developed with variable-stability helicopters, small V/STOL research aircraft, and ground simulators.

Because relatively little design information is available on lift-fan VTOL concepts which look attractive for large higher-speed transports, more emphasis is now being placed on this concept in our research programs. This figure shows a lift fan model tested last year in the 40-by 80-foot tunnel. One of the geometric variables studied in these studies, was the effect of fan location on wing aerodynamic lift characteristics for this configuration the forward fans were found to have an adverse effect, the rear ones, a larger favorable aerodynamic effect. Other design variations resulting from suggestions arising from the industry studies are planned. This model was tested more recently. It is very similar to one of the designs considered in the contractor studies.

The contractor study results emphasize that the lift-fan VTOL designs require development of engines having higher thrust to volume ratio, and methods of obtaining hover and transition control requirements with less power loss from the engines. One method for obtaining the reduction in power required for control may be through the utilization of direct translation control devices--vanes to deflect the jet exhaust--for forward and sideward maneuvering, rather than the normal lateral and pitch rotary motion. An extensive ground simulation and flight research program has been started to examine this method of control.

The importance of a zero-visibility landing operational capability for commercial short take off and landing aircraft was noted previously. This capability will have an even greater significance for VTOL transports because of the greater amount of fuel used in the terminal operation. Limited NASA studies are now underway to determine pilot information requirements for landing such VTOL aircraft under instrument flight conditions. The design problem for the displays required is how best to present the aircraft approach position relative to the landing site; what additional is required for VTOL operation not needed for conventional landing aircraft; and whether special information is needed in the final vertical-descent operation. In these initial tests, a conventional high-performance helicopter is being used as generally representative of a VTOL aircraft. Later studies, with the displays found to be most promising, will be conducted using other representative VTOL types having different landing approach characteristics--in particular the tilt-wing XC-142.

The problem of V/STOL noise alleviation is, of course, of particular concern. Descrepancies in the information presented by our three contractors in the original short-haul feasibility studies emphasize the need for more reliable information on noise, including more consistent methods of making measurements; we are now making arrangements to document the noise levels of available V/STOL aircraft at Edwards Air Force Base. In addition, noise investigations will be made this year with some of the large V/STOL wind-tunnel models; study of various methods of reducing noise will be included in these tests.

The third V/STOL research "mission" is the Advanced Helicopter. Although the conventional helicopter has already developed into a very valuable and successful vehicle, it has deficiencies that limit its range of usefulness. It can have very undesirable vibration characteristics; its maneuver capability is limited and not well understood; the cruise performance is poor; and the handling characteristics require a highly skilled pilot (particularly when flying under instrument-weather conditions).

NASA research to enable design of improved rotary-wing aircraft is therefore continuing. We've conducted experiments on two advanced rotor concepts in the last year which may eventually be considered promising enough for incorporation in a practical transport design. One is the hingeless rotor. The essential basis of this concept is the removal of the flapping and lagging hinges used on the conventional articulated rotor, and mounting the rotor blades directly to the rotor drive shaft. The large rotor-hub moments developed are transferred directly from the rotor to the fuselage--not possible with the hinged blade--providing a strong source of control and damping power. The elimination of the hinges also can provide a significant reduction in rotor-hub complexity, maintenance, and hub aerodynamic drag. Actually, the hingeless rotor is not new, having been tried in the early development of the autogyro and helicopter; at that time, the concept was abandoned primarily because of high blade stresses of the hub associated with the relative inflexibility of the rotors used. Hinges at the blade root were then incorporated to alleviate these stresses. The hingeless rotor concept, but with the flexible blades was studied later by wind-tunnel tests and found to be promising. NASA flight research of the hingeless blade rotor has been conducted over the last few years, initially with a modified Bell H-13 helicopter. For the last several months, Langley has been using the Lockheed XH-51 which was designed specifically around the hingeless-rotor concept.

The right side of the right figure illustrates the large increase in control power and damping possible with the hingeless rotor helicopter as compared with the conventional hinged rotor. These flight studies will continue, looking further into such problems as gyroscopic coupling which can cause unsatisfactory handling-quality characteristics for relatively heavy hingeless-blade helicopters.

Although the elimination of the rotor-blade flap and lag hinges also achieves considerable reduction in vibration, some vibration remains, associated with the rapid oscillating changes in rotor-blade pitch angle required to maintain the same lift on the advancing and retreating blade in forward flight. Another new rotor conept, originated in France, shows promise of further reducing vibration by avoiding the necessity of changing blade pitch. In this concept--called the jet-flap rotor--a sheet of air is blown from the trailing edge of the rotor airfoil, increasing air circulation over the blade, delaying flow separation and vibration. Lift is controlled by varying the angle of the jet and cyclic deflection of the jet is used instead of blade-pitch deflection for control and maneuvering. The jet sheet also acts as the force to turn the rotor, eliminating the conventional rotor drive shaft. The intent of the design is, then, to reduce the vibration level for a given forward speed and loading, and to permit larger propulsive and lift loads.

Last year, we undertook a wind-tunnel program with the U.S. Army to investigate the jet-flap-rotor concept at large-scale. The results show the vibration level of this rotor is about 80% less than for conventional hinged-blade rotors; the blade flapping is about 85% less, that remaining resulting from bending of the flexible rotor blade. This is a photograph of the jet-flap rotor model--with some of the test equipment required for its operation--in our Ames 40-by 80-foot wind tunnel.

The next figure compares the <u>lifting</u> capability of the jet-flap rotor (the symbols) with a conventional rotor (the lower blue band) having the same dimensions and tip speed. A substantial increase in lift capability is shown throughout the speed range tested. In addition it appears it may be usable up to higher speeds. The upper speed limit for the conventional rotor (about 180 knots) is limited primarily by flow separation or stall of the retreating rotor blade. Jet-flap rotor data were not obtained at much higher forward speeds in our investigation because of limitations in the model. However, there were no indications of retreating blade stall up to the speed limits tested. The upper yellow band is the calculated performance of this rotor, and indicates a capability of pure helicopter flight to forward speeds of perhaps 300 knots. The Army and the NASA have now jointly funded a second jet-flap rotor, more representative of an actual design to be tested later this year. It will, for example, have improved ducting and better jet flap permitting larger deflection angles; such changes to the model design and use of another, higher pressure-ratio gas generator to drive the rotor and control the jet, are expected to permit greatly improved harmonic cycling and reduced vibration to higher speeds than those already studied. Assuming the second series of wind-tunnel tests continue to indicate the promise of this concept, eventual flight verification of the characteristics is tentatively planned.

Wind-tunnel experimental studies of relatively-conventional articulated rotor concepts will also continue. Tests were recently completed in the 40-by 80-foot tunnel of rotor stability and aerodynamic characteristics at high tip speeds on two full-scale rotors provided by the Army.

Some research has also been conducted to effect a substantial increase in the maximum speed of rotor aircraft by "compounding" the helicopter, that is, utilizing a separate forward propulsion system and a wing to take over the load of the rotor in forward flight. Several versions of the compound concept have been proposed by industry. The next figure shows a stopped and folding rotor concept recently studied in the 40-by 80-foot tunnel in a joint NASA-Navy research program.

As you may recall, this concept was used in one of the VTOL transport designs proposed in the contractor studies. Our wind-tunnel tests, of a 33-foot rotor, have indicated some instability problems of the rotor blades in starting and stopping of the rotor. Additional problems are expected for substantially larger rotors; a rotor of about 130-feet diameter will be required for a 120-passenger transport. The tests have also shown drag levels of the hub with the rotor stopped and folded which result in severe reductions in cruise speed. It will probably be necessary therefore to store the rotor and hub in cruise flight such as is indicated in this typical application suggested by Lockheed. The mechanism required to provide the folding and stowing capability is expected to result in some weight penalty.

Solution of the problems associated with this and other composite rotor systems could allow design of VTOL aircraft with less compromise penalty between hovering and forward flight efficiency. Such an aircraft has the potential for realizing the low rotor disc loading required for operation from small, unprepared sites, and a cruise efficiency significantly higher than that of the "pure" helicopter. The anticipated lower noise levels in take-off and landing--compared to that of other VTOL concepts--would be another significant advantage for commercial use especially if the noise research mentioned previously does not lead to substantial reductions in noise for the other VTOL transport concepts. Additional NASA exploratory research on this and other compound concepts is therefore planned.

The general problem of alleviating the basic poor handling qualities of helicopters at low speed will receive continued study with a primary aim of reducing the requirements for pilot skill. Really substantial improvement will probably be possible only through use of improved automatic stabilization equipment. An understanding of the requirements for such handling qualities is being obtained from flight studies with our variable-stability helicopter a modified Army CH-46 vehicle. Present factors studied include requirements for control of vehicle height (as influenced by response of the engine for example), and effect of longitudinal stability on control power and damping requirements.

The only supersonic-speed aircraft utilizing VTOL capability that we foresee in of least the next ten years is the Military Tactical Fighter, the last NASA V/STOL mission category. Our research on this mission will be aimed at providing more reliable information--especially relating to landing operation in zero-visibility weather--for design of an advanced production aircraft. Some of the research should eventually have application to higher-speed commercial V/STOL aircraft. The major critical problem areas for the VTOL tactical aircraft are listed here. In particular, there is a lack of information on level of control power and automatic stabilization required; on the necessary landing aids and pilot displays; and on piloting and operating procedures during the landing approach to a small VTOL landing site under instrument weather conditions. These problems are especially critical for jet V/STOL aircraft because of the very large amounts of fuel used by the jet during the instrument approach.

Requirements for minimum control power in hover and transition for this type of aircraft will be studied in flight initially with a direct-jet-lift P-1127 recently assigned to Langley by the DOD. The aircraft will be used to define more precisely the problems involved in the terminal operation, including some effects of piloting technique. Related information with the X-14 variable-stability aircraft with which promising control and stabilization systems are being evaluated.

Additional information on defining criteria for establishing minimum power control requirements for this--and other V/STOL types--is being obtained on our new 6-degree-of-freedom motion simulator.

A motion picture has been prepared which demonstrates the operational capability of the simulator. The first sequence shows our X-14 deflected-jet VTOL airplane taking off and going through typical hover maneuvers.

This is the six degree of freedom simulator; in this case the simulator is programmed to match the control response and damping characteristics existing in the X-14 airplane shown just before. The various colors of the structure are used to better illustrate the method of obtaining the three rotary motions--yaw, roll, and pitch. Linear longitudinal, lateral, and directional motions are also illustrated. Here again is the X-14, in typical maneuvers that might be required in making a vertical landing in a restricted site. Results so far show the flight and simulator results are in very good agreement.

This facility makes possible the investigation of damping and control conditions that might be catastrophic in flight. In addition, it has been used in as a pilot training aid in programs on specific V/STOL aircraft, some of which are illustrated here.

Wind-tunnel studies will also continue this year on models of jet VTOL configurations. Particular attention is being given to interference effects induced on the airplane by the interaction between the free stream and the jet wakes during transition flight which can result in adverse effects on stability, control requirements, and lift.

Another serious problem being studied in such model tests is the recirculation of engine exhaust gases in hover, take-off, and landing which can lead to hot-gas reingestion, causing increased intake temperature and greatly reduced engine performance; it has been shown for example that a 40° increase in temperature at the engine intake results in about a 15% loss in engine thrust.

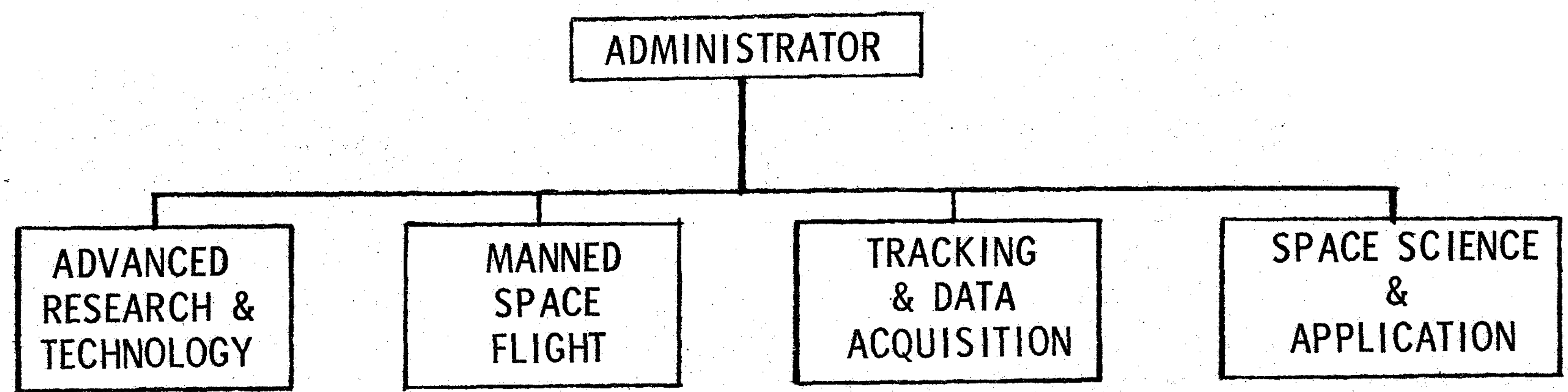
Pilot-display requirements for zero-visibility landing operation are presently being studied using the high-performance helicopter mentioned earlier as an instrument carrier; studies of the most promising displays will probably be continued with the P-1127 aircraft.

Our propulsion research program will also emphasize studies of engine components to enable development of higher thrust to volume and thrust to weight ratio engines suitable for this type of aircraft.

CONCLUSION

We have, of course, many other research programs on each of the four V/STOL missions mentioned. We believe that our overall V/STOL program--together with those of the FAA, other government agencies, and of the industry itself--will provide the necessary base for the improved design of aircraft required to bring about the greatly expanded use envisioned.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



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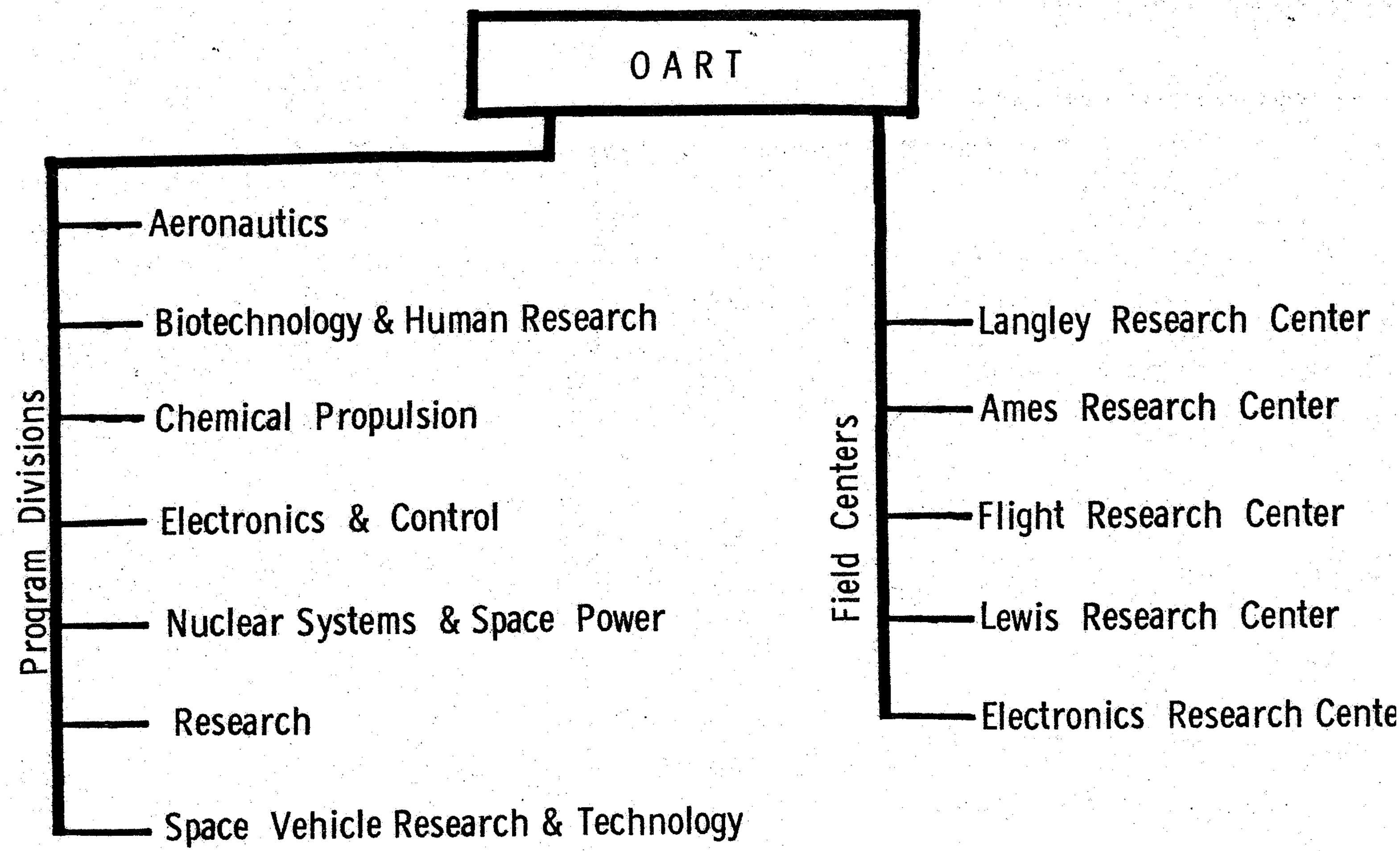
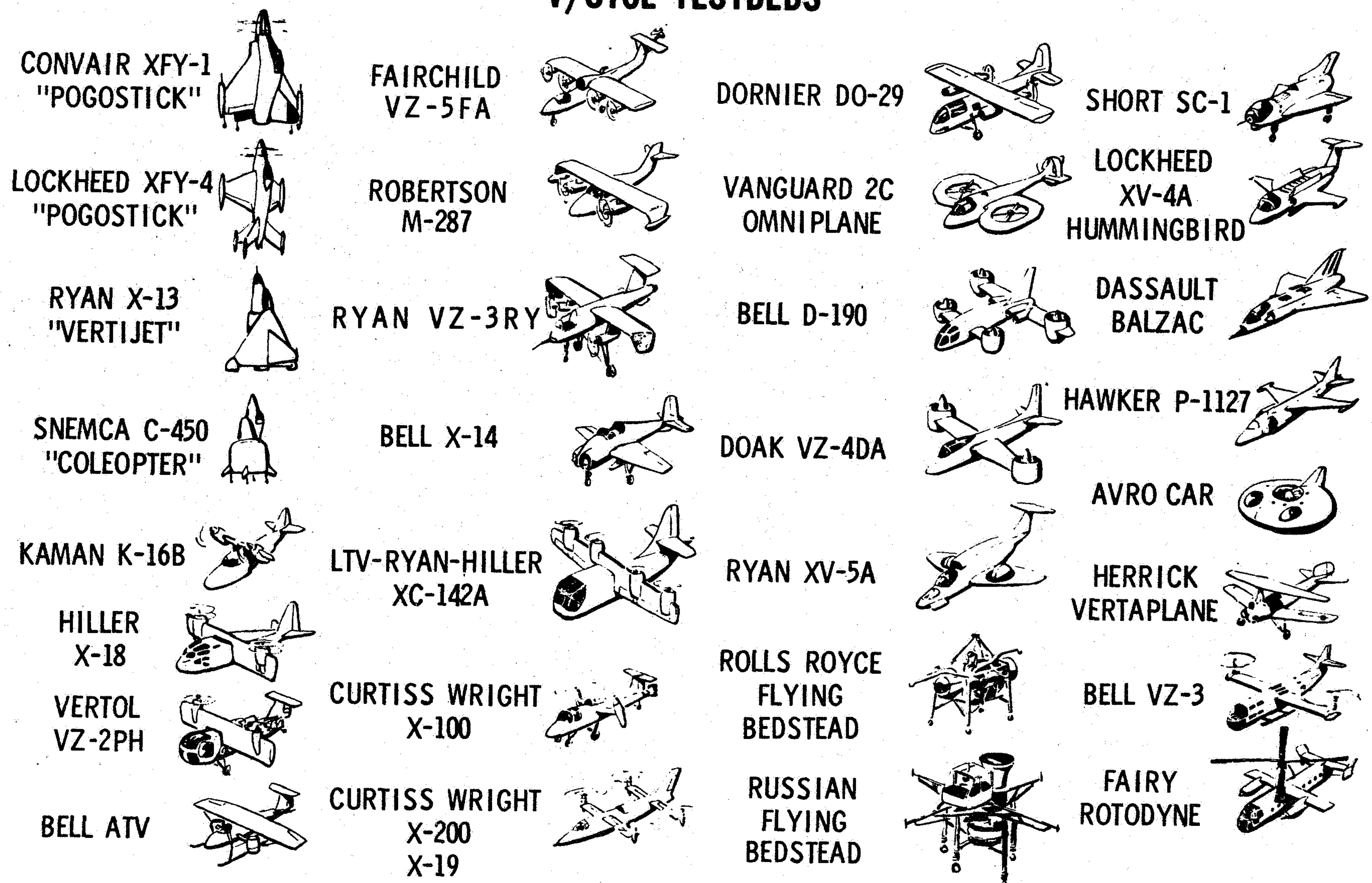


V/STOL TESTBEDS



NASA RA 66-855
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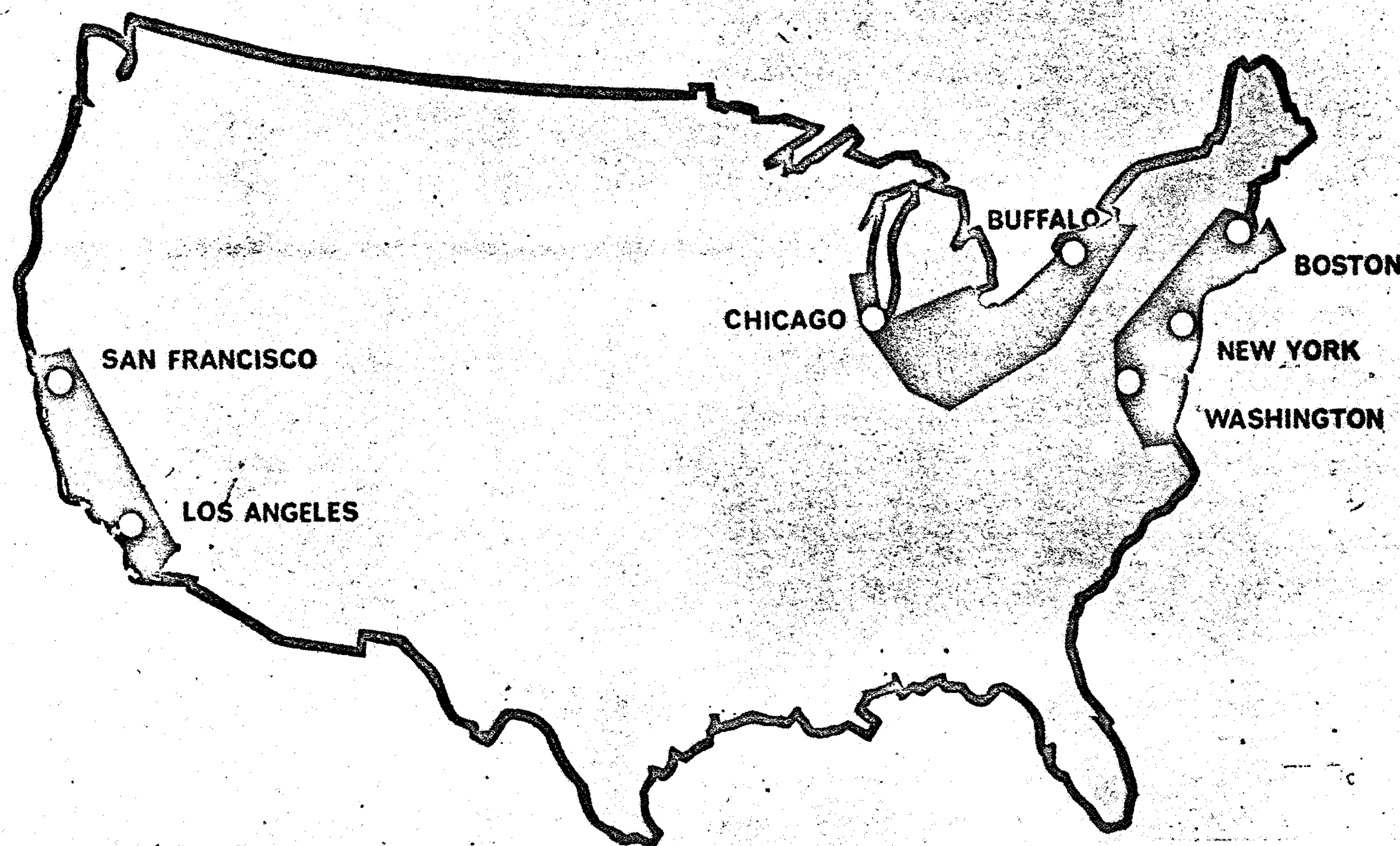
EMERGING MAJOR METROPOLITAN REGIONS



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FEASIBILITY STUDIES OF V/STOL CONCEPTS FOR SHORT-HAUL COMMERCIAL TRANSPORT AIRCRAFT

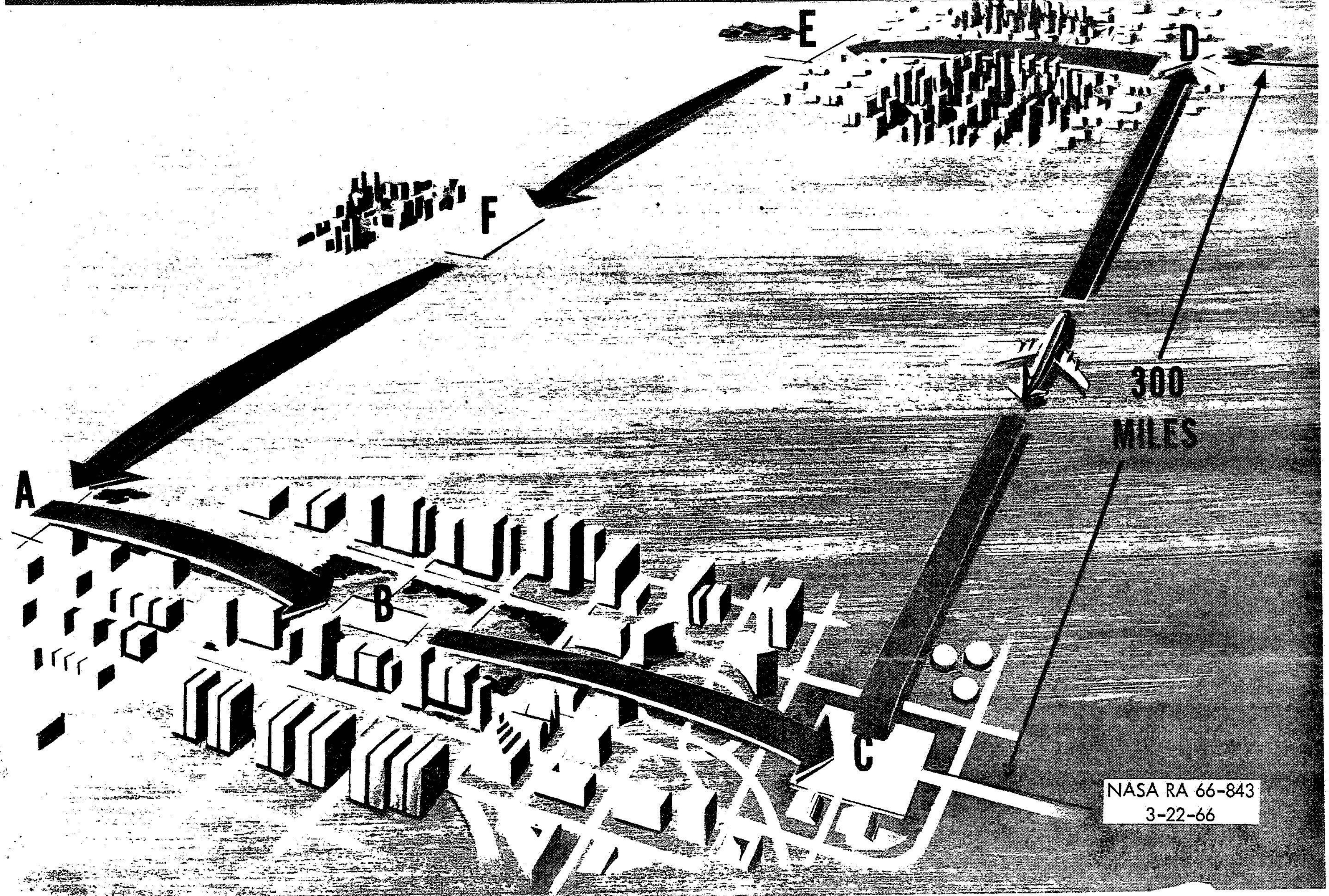
TO DETERMINE:

- MOST PROMISING V/STOL CONCEPTS
- PROBLEMS REQUIRING RESEARCH

NASA RA 66-763
3-22-66

V/STOL FEASIBILITY STUDIES

TYPICAL ROUTE FOR COMMERCIAL V/STOL AIRCRAFT



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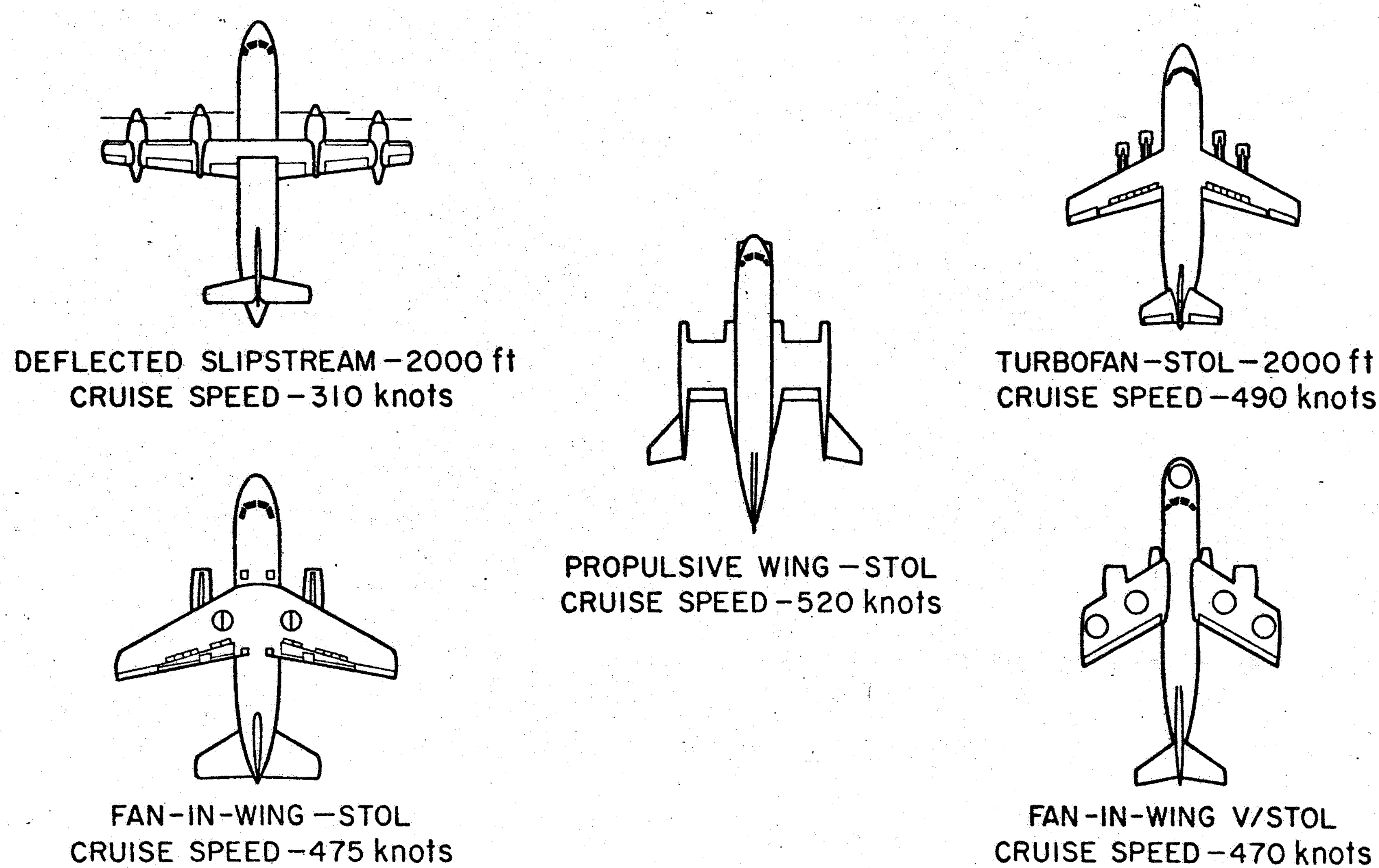
STOL CONCEPTS UNDER STUDY



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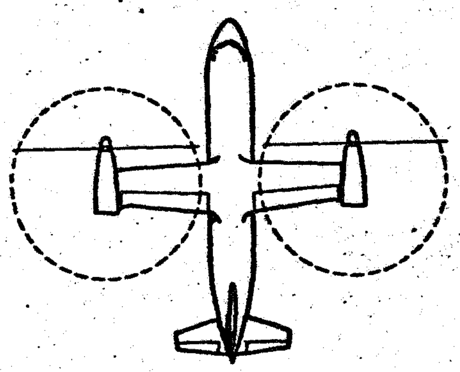
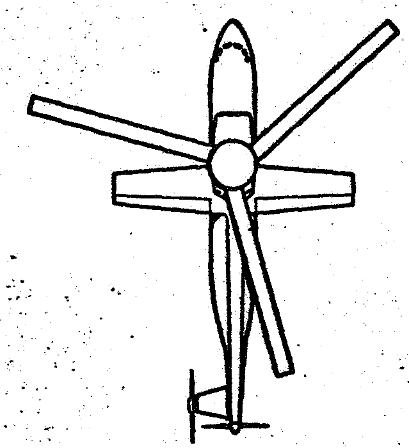
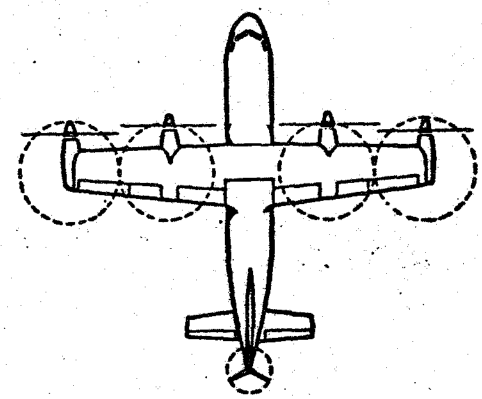
VTOL CONCEPTS UNDER STUDY



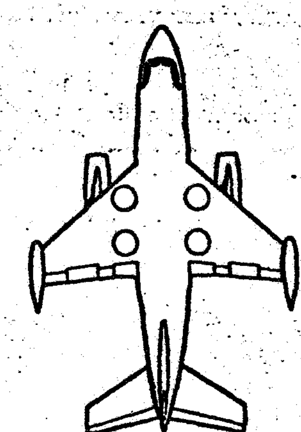
TILT ROTOR-VTOL
CRUISE SPEED-390 knots



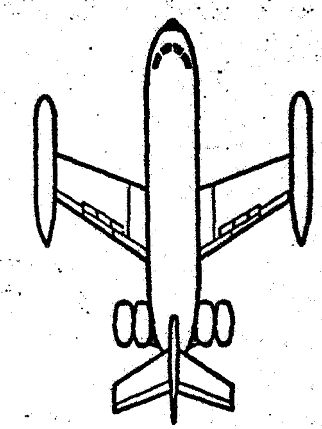
STOPPED-STOWED ROTOR-VTOL
CRUISE SPEED-355 knots



PROPELLER TILT WING VTOL
CRUISE SPEED-370 knots



LIFT-FAN-VTOL
CRUISE SPEED-470 knots



JET LIFT-VTOL
CRUISE SPEED-457 knots

V/STOL FEASIBILITY STUDIES
CONCEPTS CONSIDERED

BOEING	LING-TEMCO-VOUGHT	LOCKHEED
<u>TILT-WING V/STOL</u>	<u>TILT-WING V/STOL</u>	TILT-WING V/STOL
PROPELLER STOL	<u>PROPELLER STOL</u>	PROPELLER STOL
<u>TURBOFAN STOL</u>	TILT-WING STOL	JET-FLAP STOL
FAN-IN-WING STOL	FAN-IN-WING STOL	<u>FAN-IN-WING STOL</u>
FAN-IN-WING VTOL	<u>FAN-IN-WING VTOL</u>	<u>TILT-ROTOR V/STOL</u>
STOWED-ROTOR V/STOL		<u>STOWED-ROTOR V/STOL</u>
<u>LIFT-FAN V/STOL</u>		LIFT-CRUISE FAN V/STOL
<u>JET DIRECT-LIFT V/STOL</u>		

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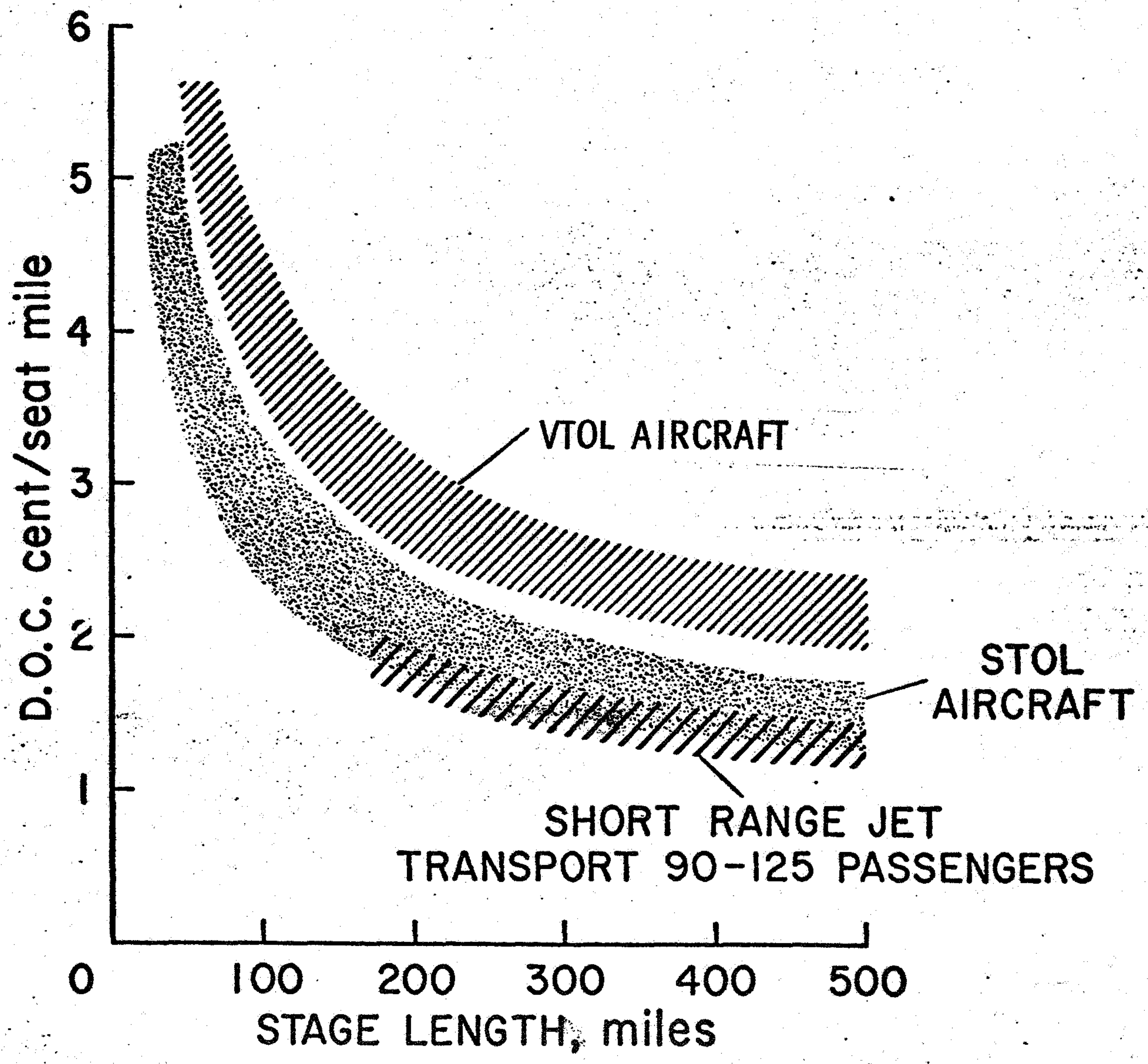
3-22-66

AAA120-10

D.O.C. VS STAGE LENGTH 120 PASSENGER AIRCRAFT



CONCLUSIONS

POTENTIAL FOR ECONOMIC V/STOL TRANSPORT GOOD

- COMMUNITY NOISE A MAJOR DESIGN CONSIDERATION
- NEED FOR ADVANCED TERMINAL AREA GUIDANCE AND CONTROL SYSTEMS
- SIGNIFICANT RESEARCH AND DEVELOPMENT REQUIRED

NASA V/STOL RESEARCH MISSIONS

- STOL TRANSPORT
- VTOL TRANSPORT
- ADVANCED HELICOPTERS
- SUPERSONIC VTOL (TACTICAL)

STOL COMMERCIAL SHORT-HAUL TRANSPORT

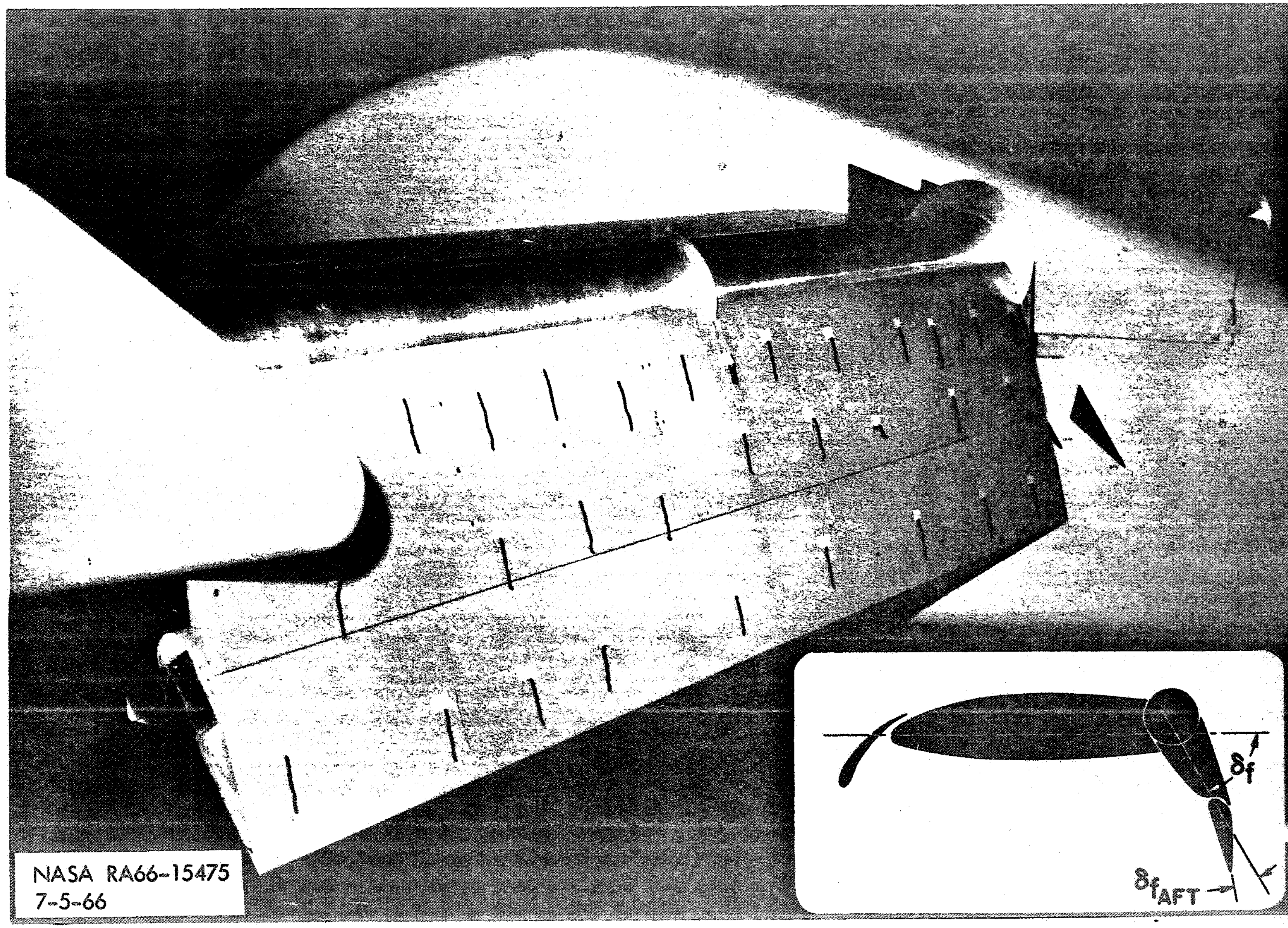
CRITICAL PROBLEM AREAS

Efficient Conversion of Power to Augment Lift

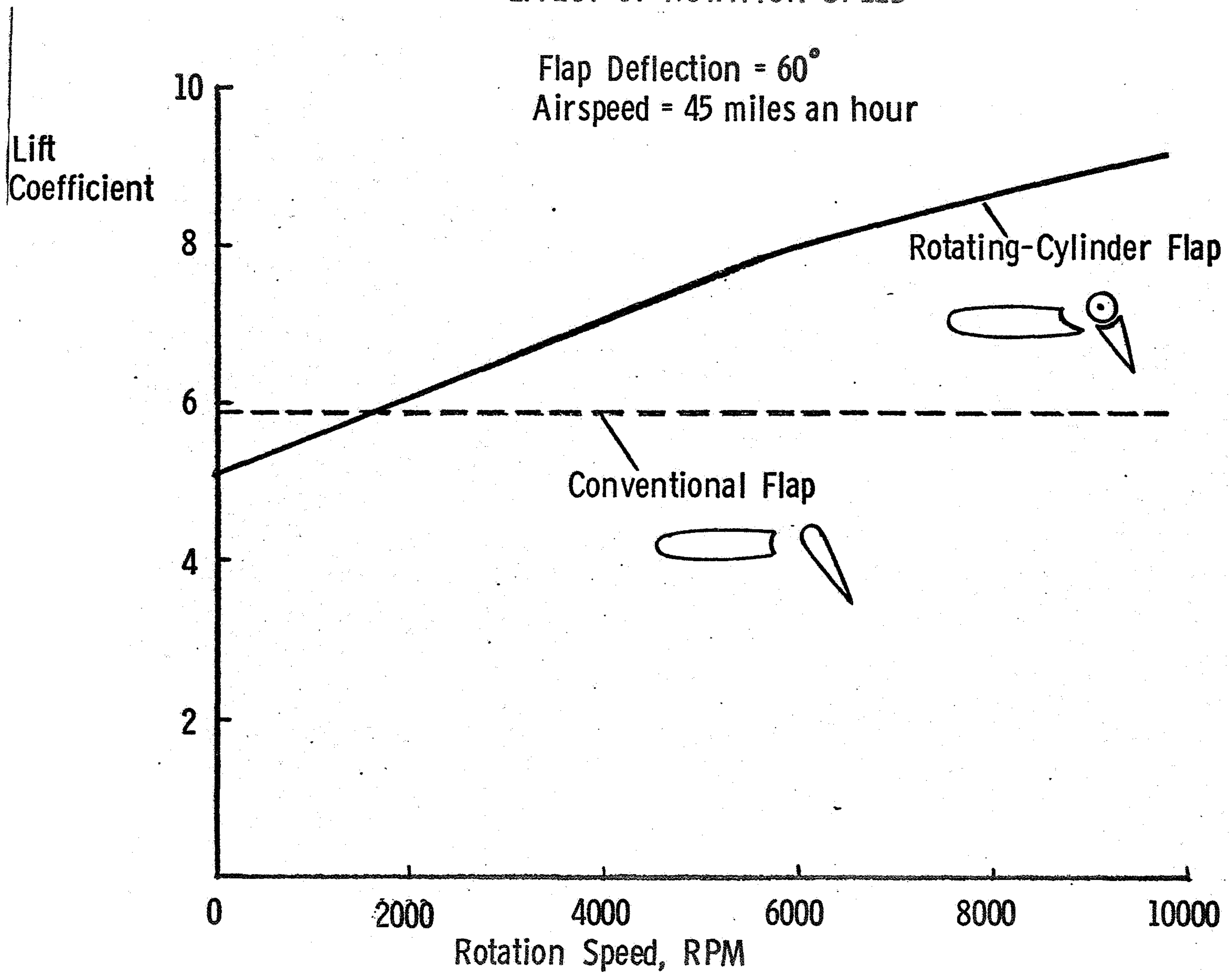
Low-Speed Flight Dynamics

Zero-Visibility Landing

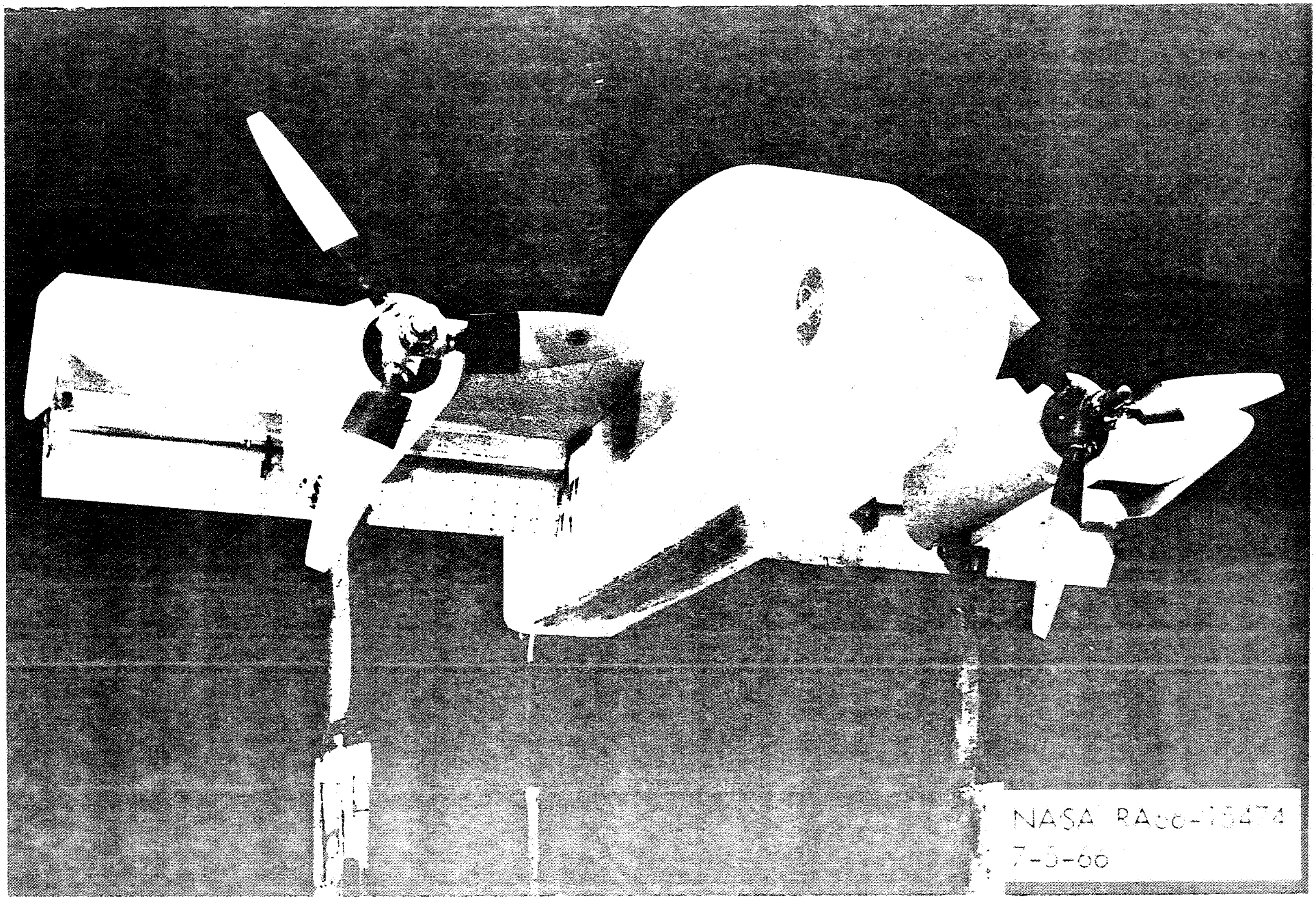
SIDE VIEW OF ROTATING - CYLINDER FLAP

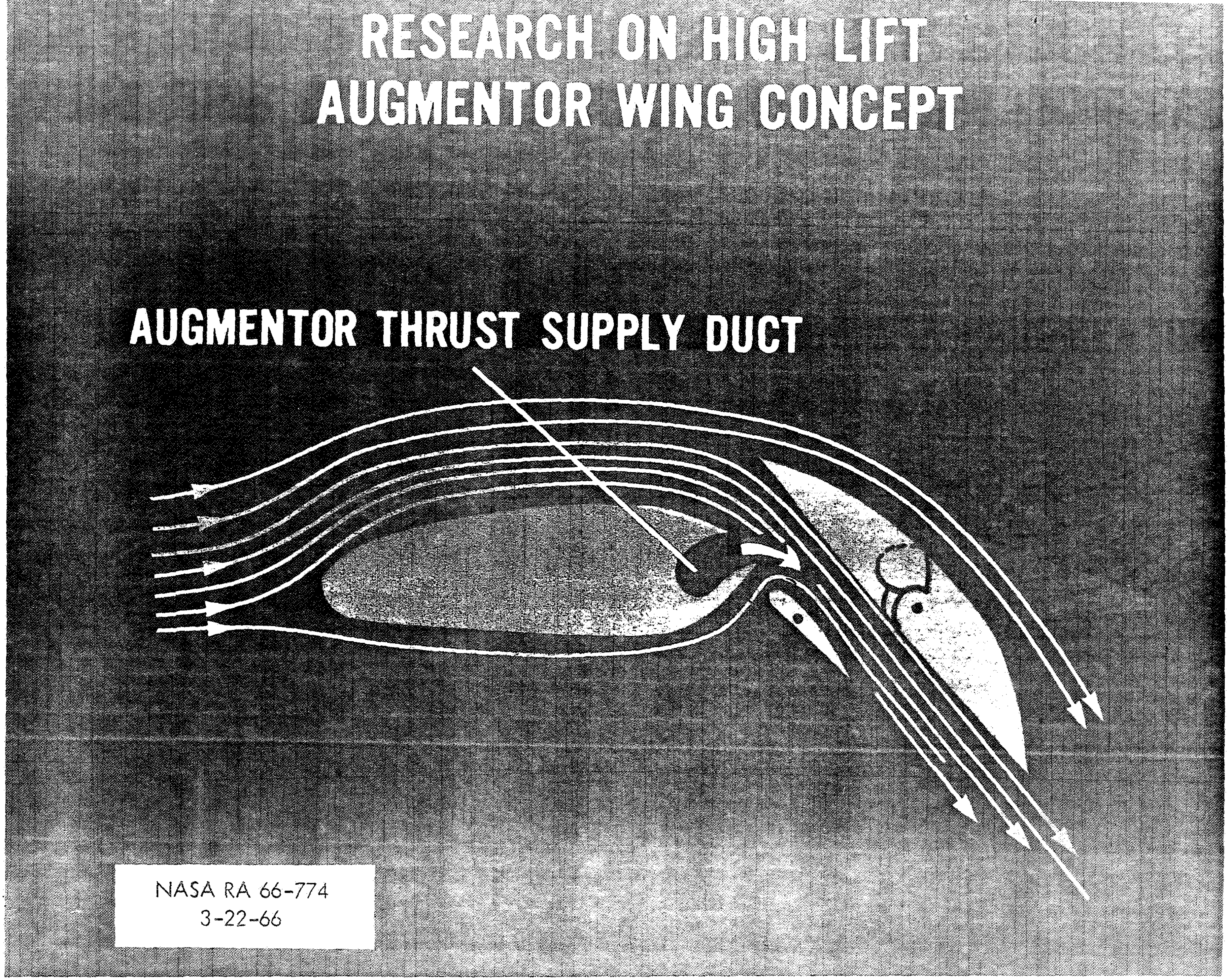


ROTATING-CYLINDER FLAP MODEL
EFFECT OF ROTATION SPEED



WIND TUNNEL MODEL WITH ROTATING - CYLINDER FLAP




RESEARCH ON HIGH LIFT
AUGMENTOR WING CONCEPT
AUGMENTOR THRUST SUPPLY DUCT
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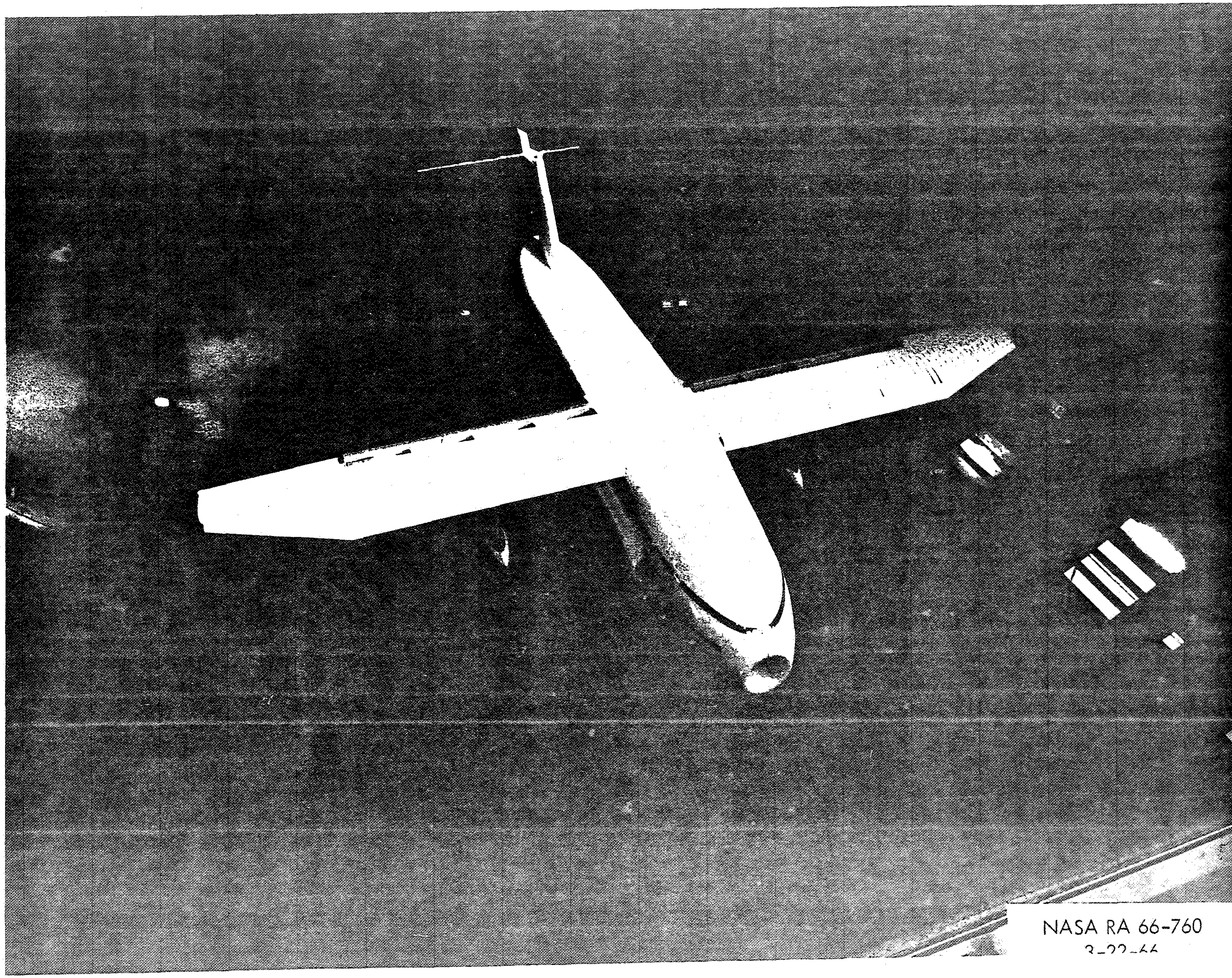
AUGMENTOR WING - WIND TUNNEL MODEL



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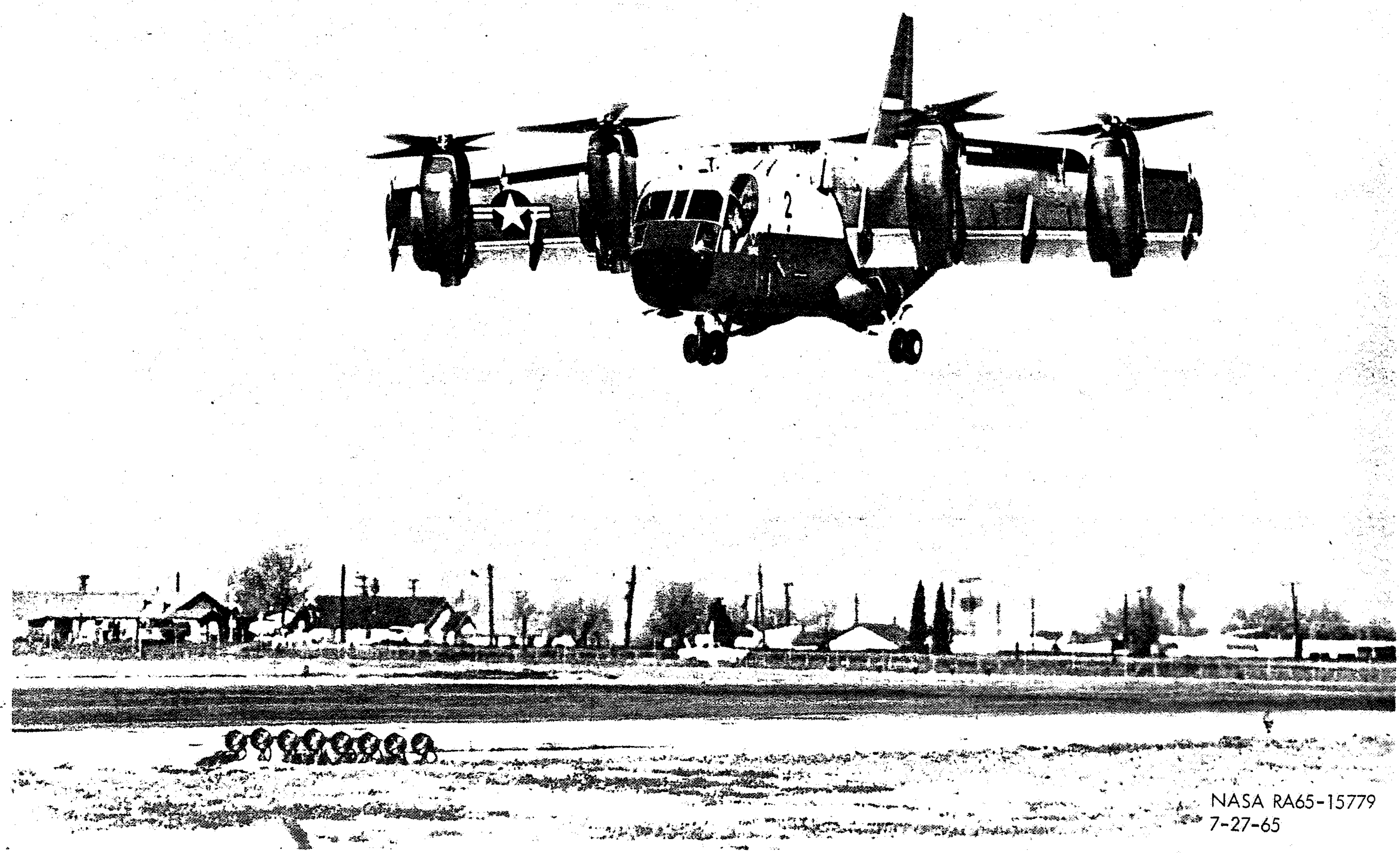
STOL RESEARCH BREGUET 941

NASA RA66-15726

LTV XC-142A TILT-WING AIRPLANE



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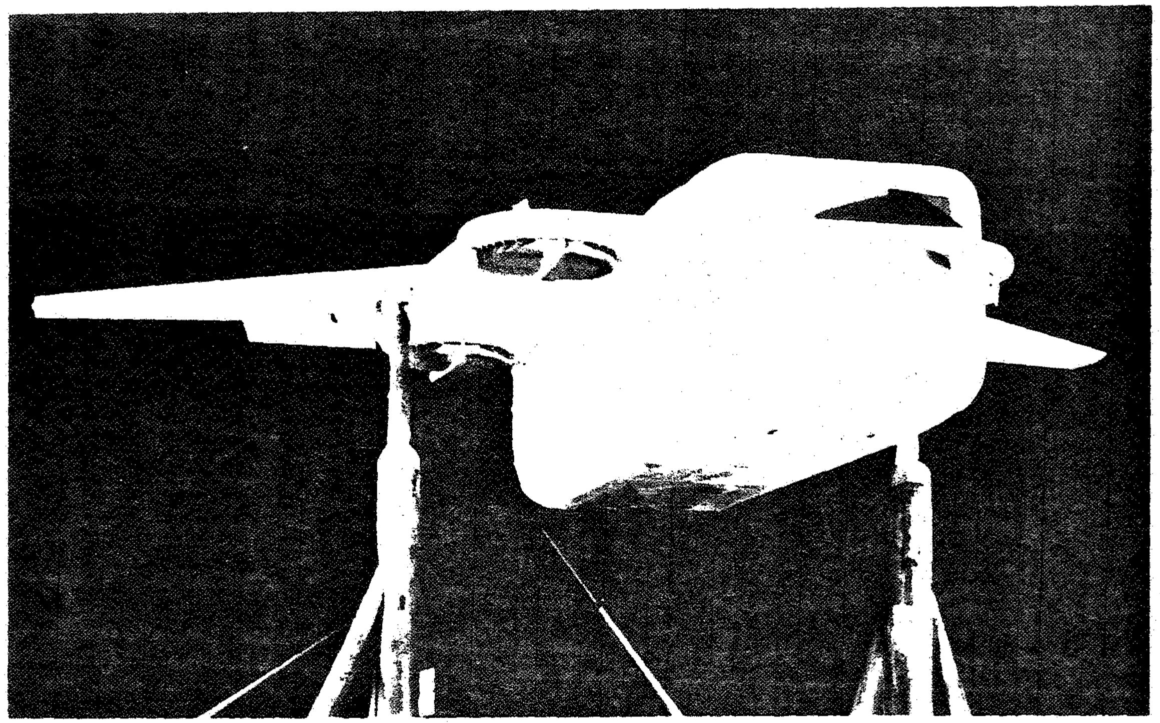
7-27-65

V/STOL MILITARY SHORT HAUL TRANSPORT

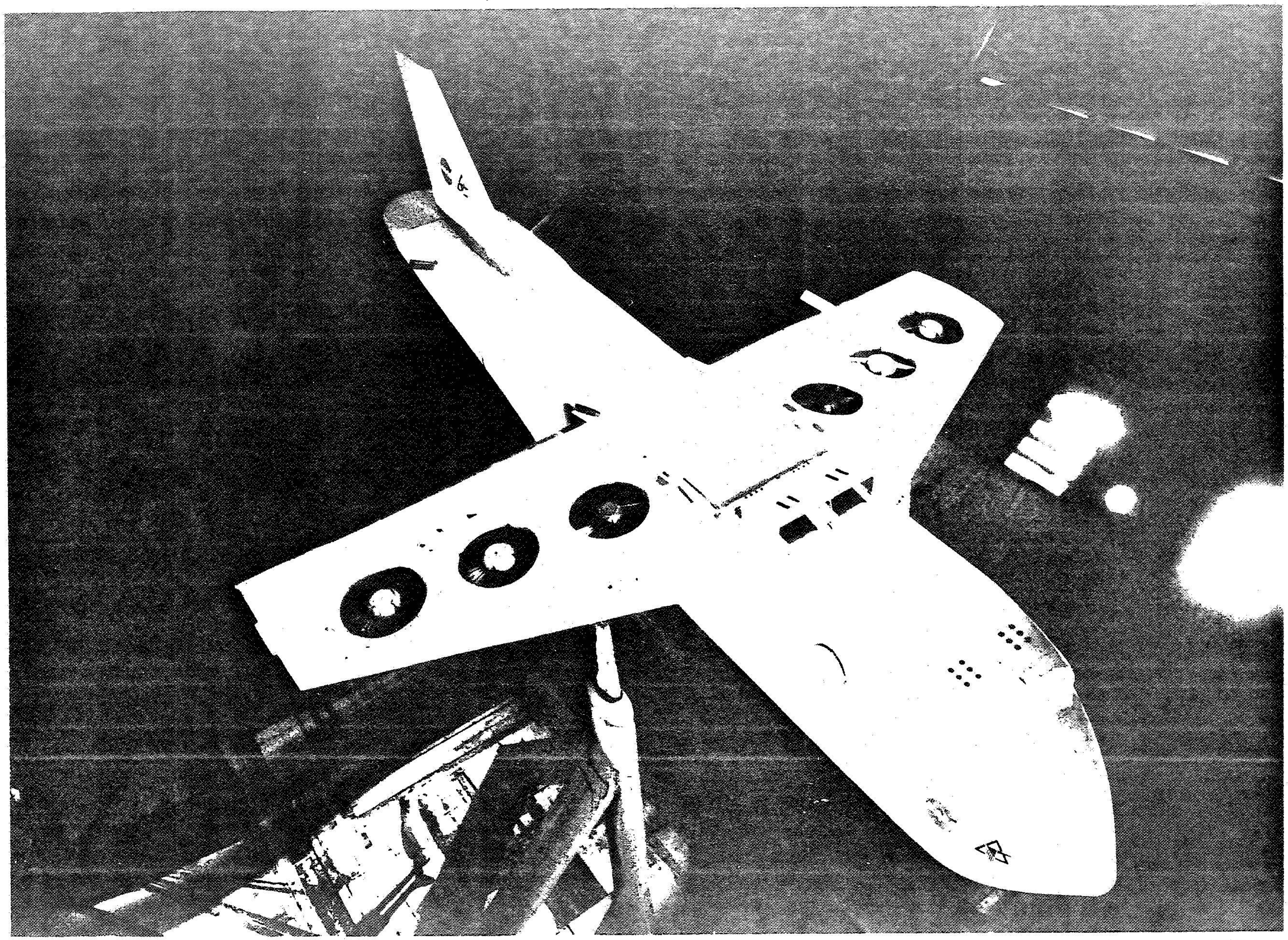
CRITICAL PROBLEM AREAS

- Ground and Aerodynamic Interference Effects
- Hover and Transition Control
- Efficient Conversion of Power to Augment Lift
- Zero-Visibility Landing
- Noise
- Propulsion System Improvement

LIFT FAN V/STOL TRANSPORT MODEL



LIFT FAN V/STOL TRANSPORT MODEL

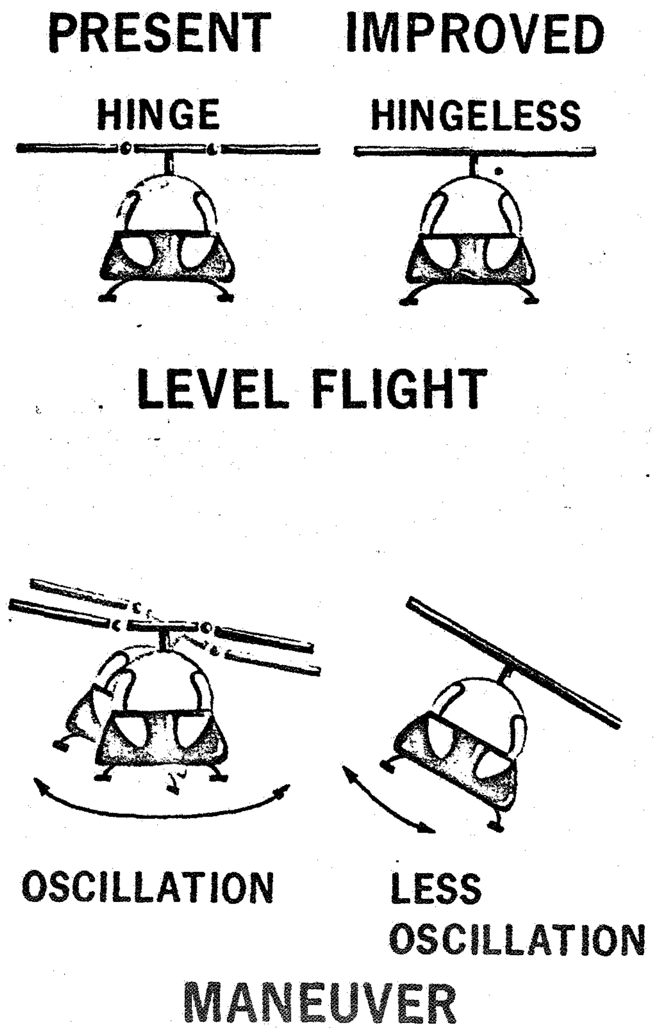


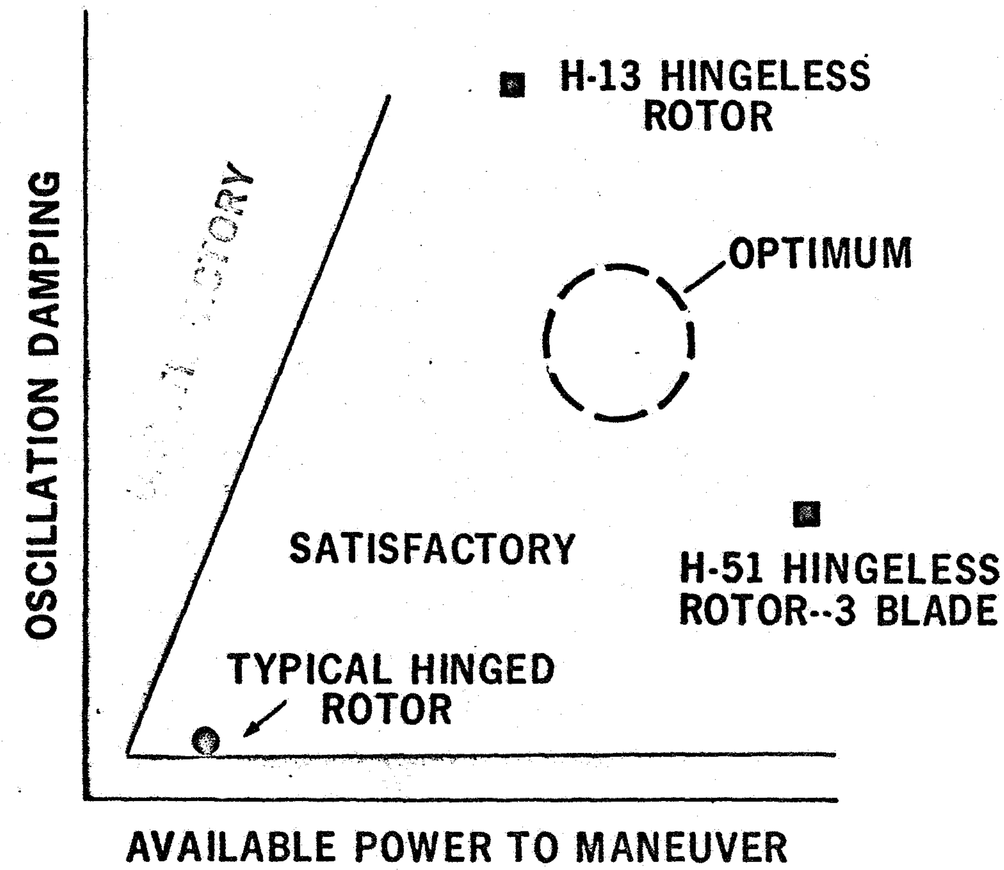
ADVANCED HELICOPTER

CRITICAL PROBLEM AREAS

- Rotor Dynamics - Vibration, Fatigue
- High-Speed Maneuverability
- Cruise Performance
- Low-Speed Handling Qualities
- Zero-Visibility Landing

HELICOPTER RESEARCH
CHANGE IN ROTOR DESIGN IMPROVES STABILITY AND CONTROL





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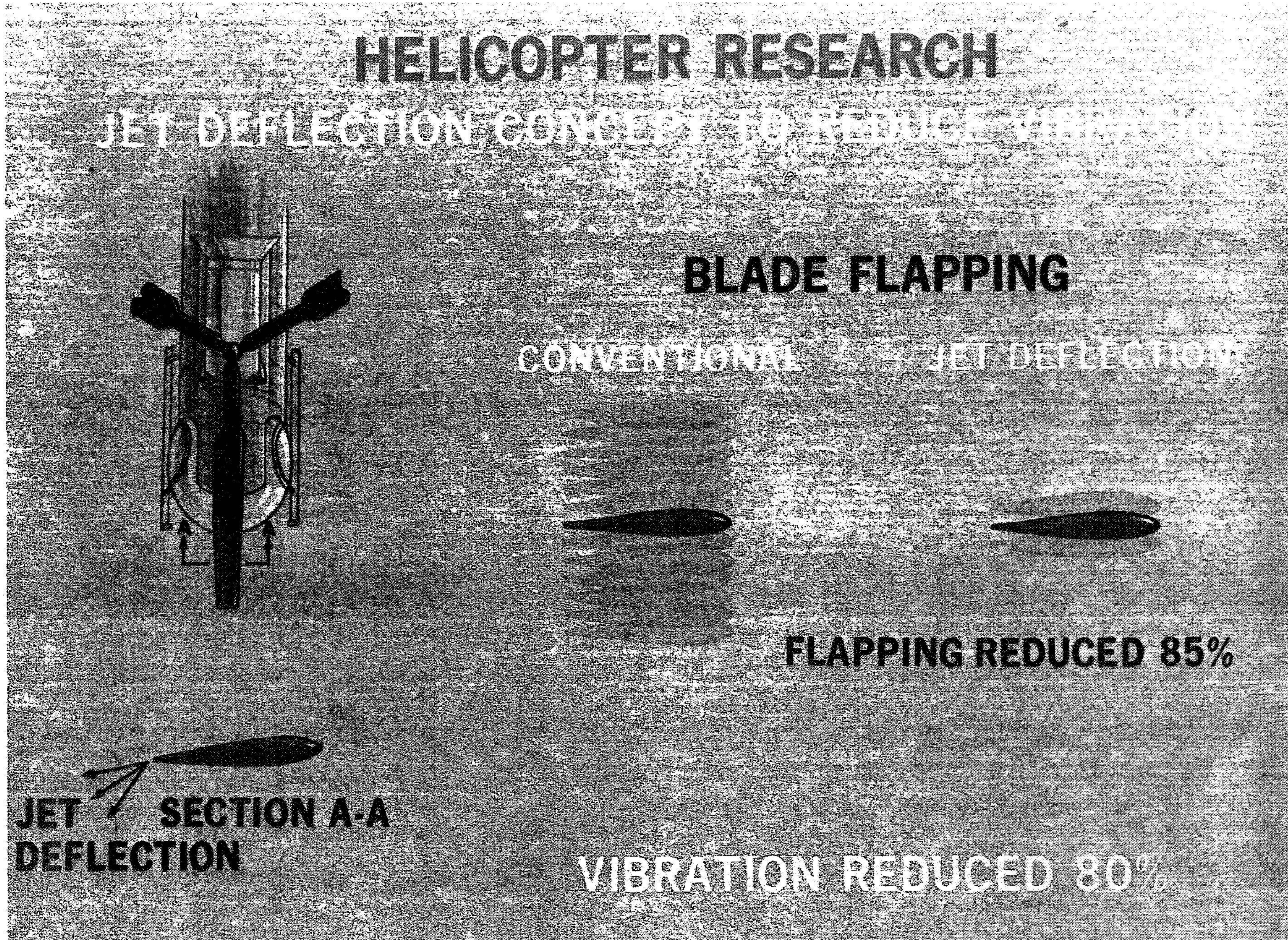
REV 3-22-66


HINGELESS-ROTOR RESEARCH HELICOPTER - H-51
NASA 30
NASA
NASA RA 66-775
3-22-66



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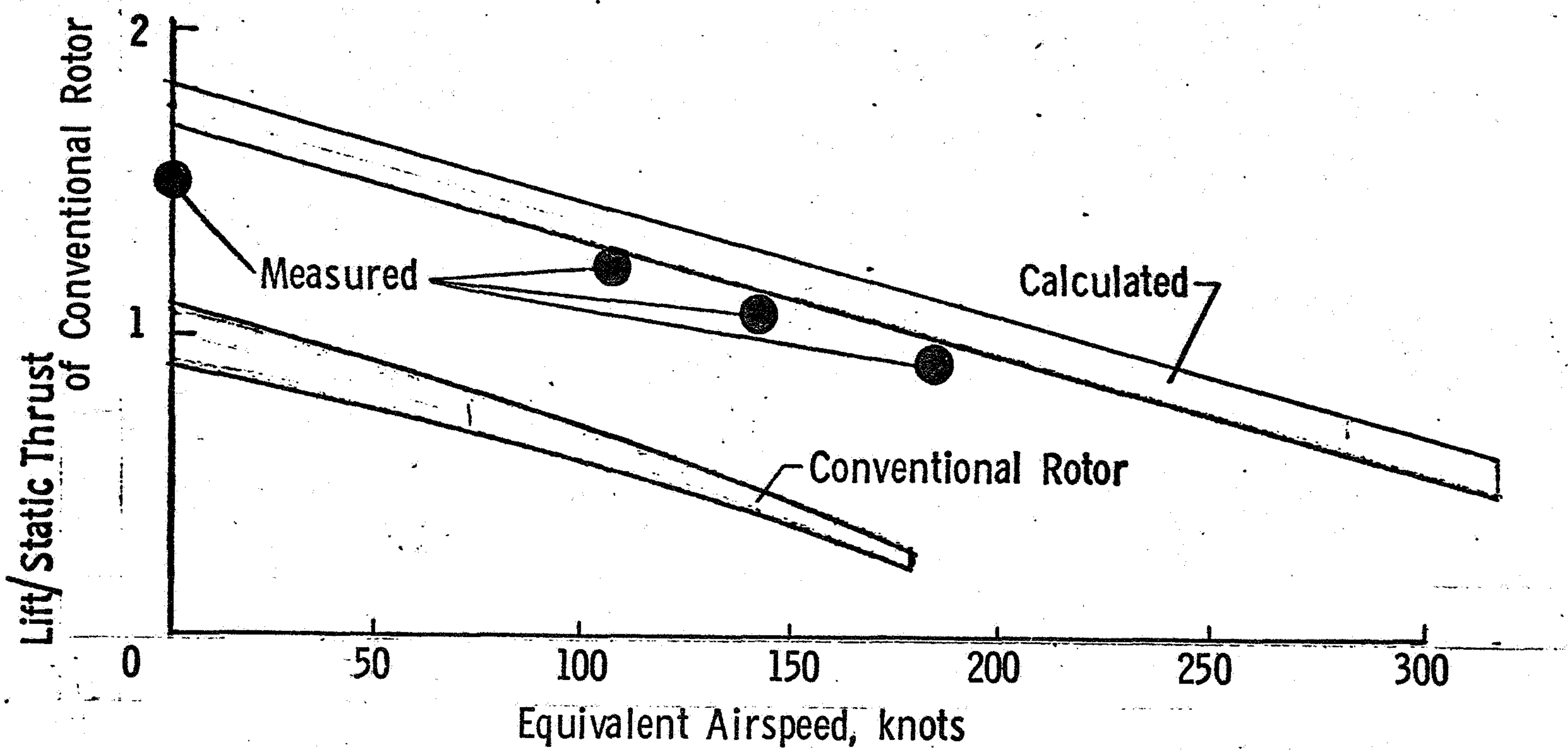
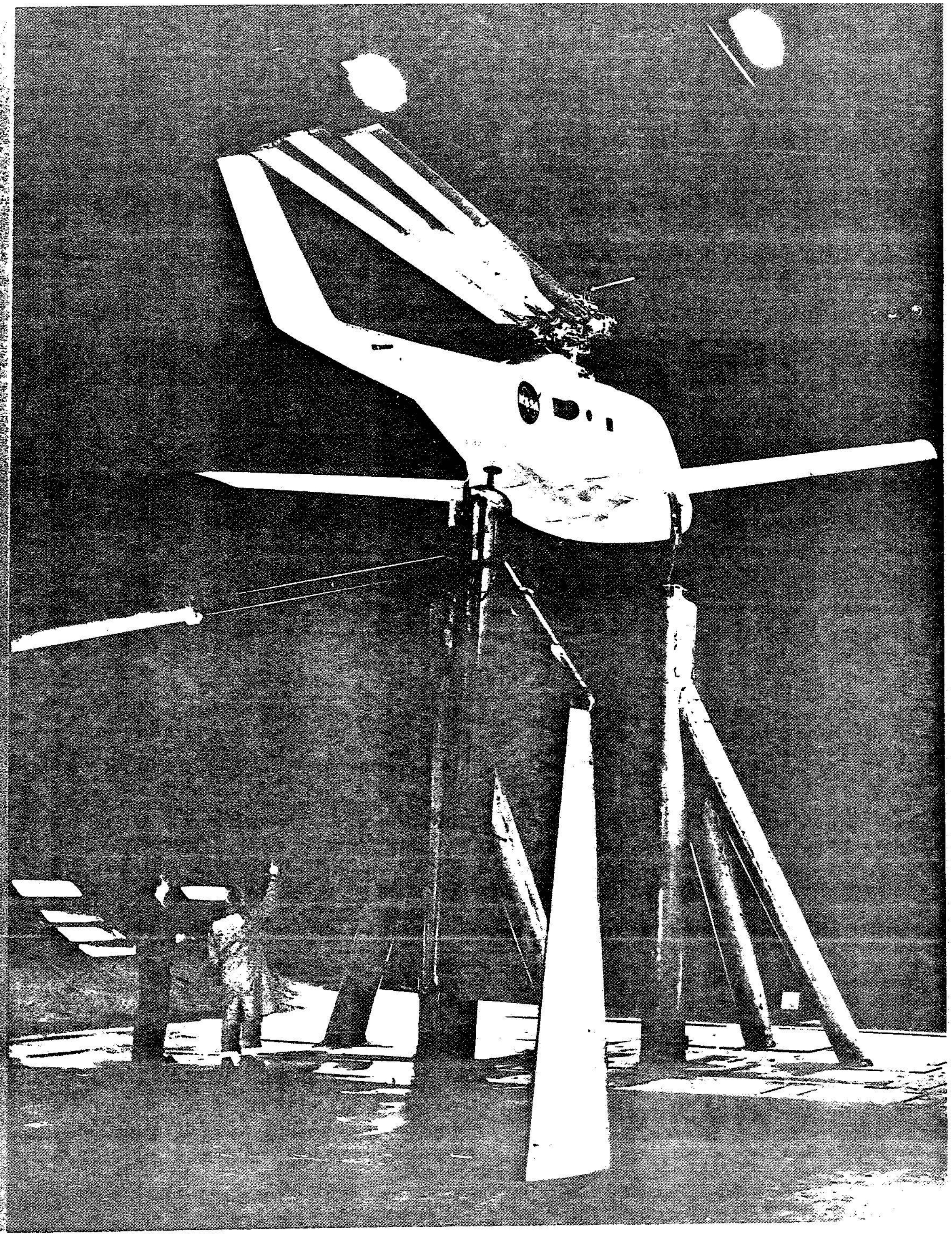
12-27-65

JET-FLAP ROTOR CAPABILITY



STOPPED AND
FOLDED ROTOR

WIND - TUNNEL MODEL



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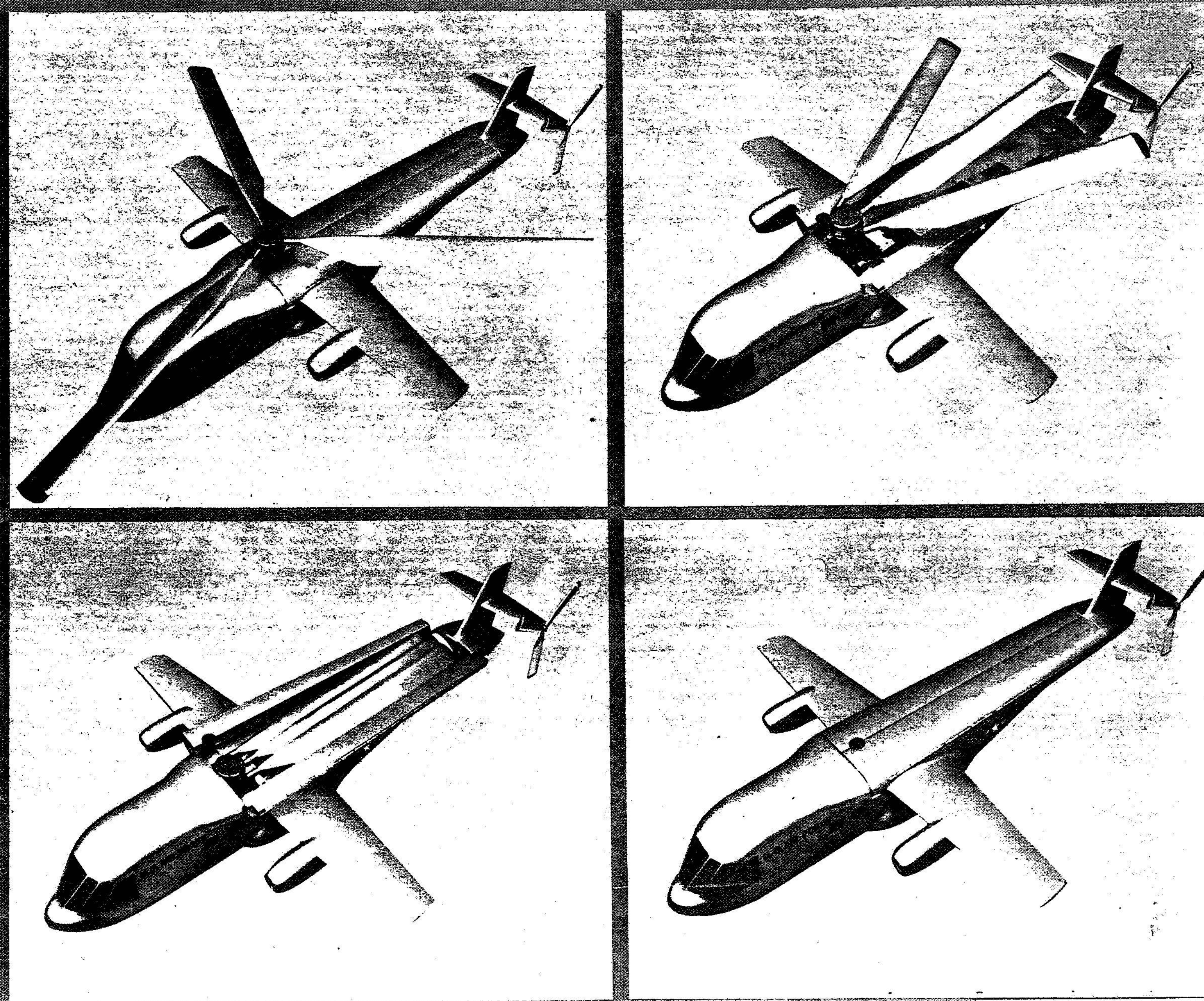
3-22-66

STOPPED AND STOWED ROTOR – TYPICAL APPLICATION



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3-22-66

CH-46 VARIABLE – STABILITY HELICOPTER

NASA RA66-15728
6-30-66

VTOL TACTICAL SUPERSONIC AIRCRAFT

CRITICAL PROBLEM AREAS

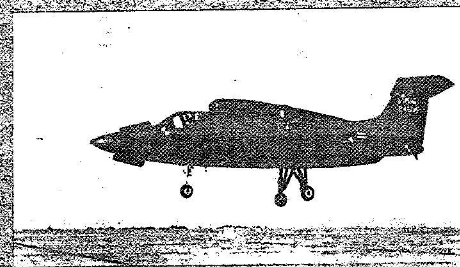
- Hover and Transition Control
- Hot Gas Re-Ingestion
- Zero-Visibility Landing
- Propulsion System Improvement

HAWKER SIDDLEY P1127

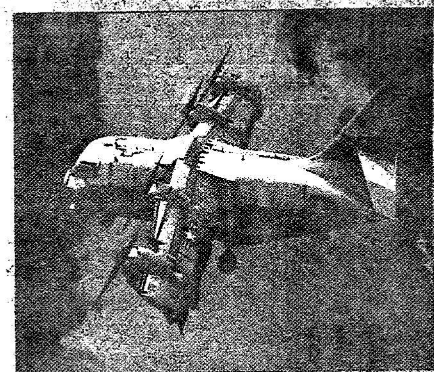
VECTORED THRUST TURBOFAN PROPELLED VTOL AIRCRAFT

NASA R63-593

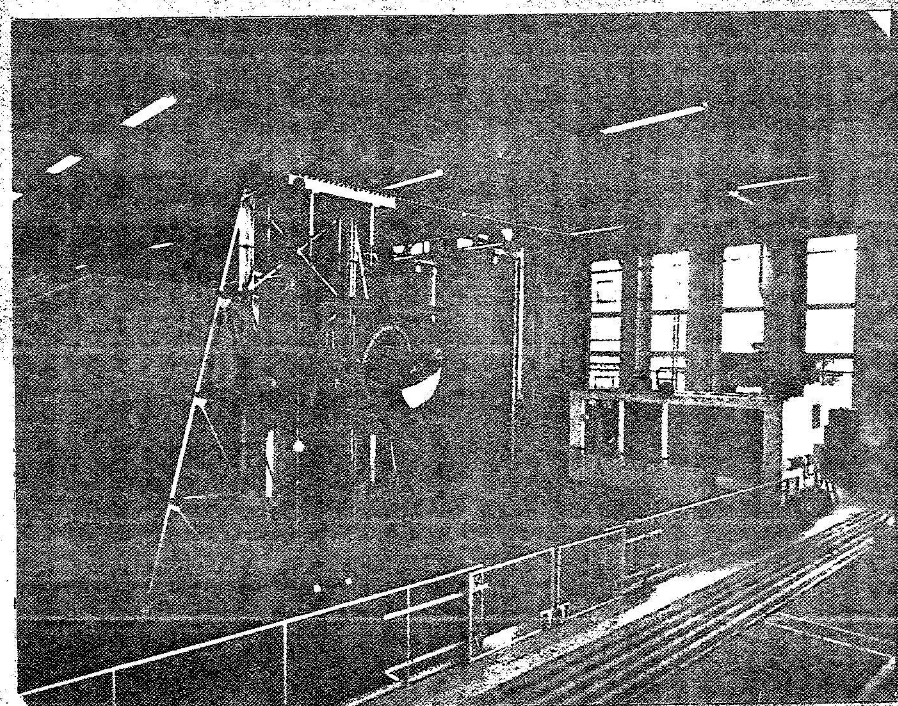
HANDLING-QUALITIES RESEARCH



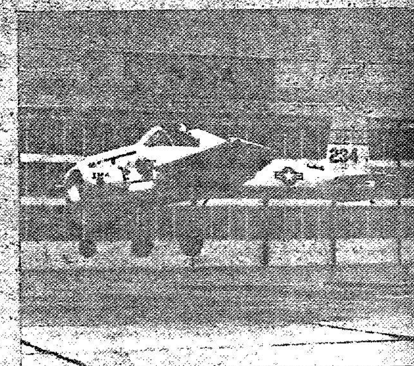
XV 5A



XC-142A



SIMULATOR



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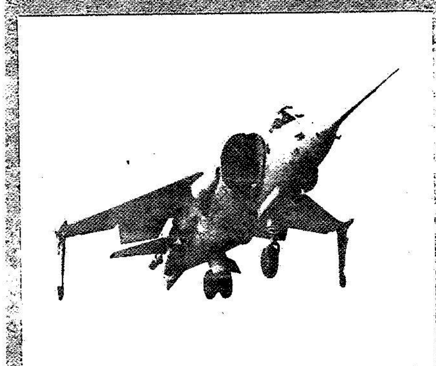

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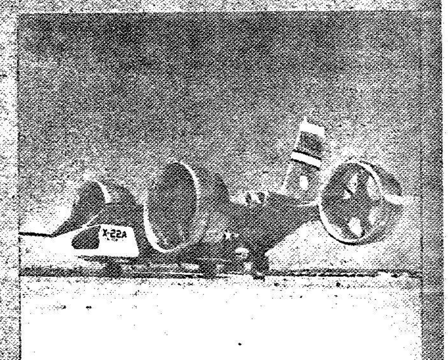

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REV 3-22-66